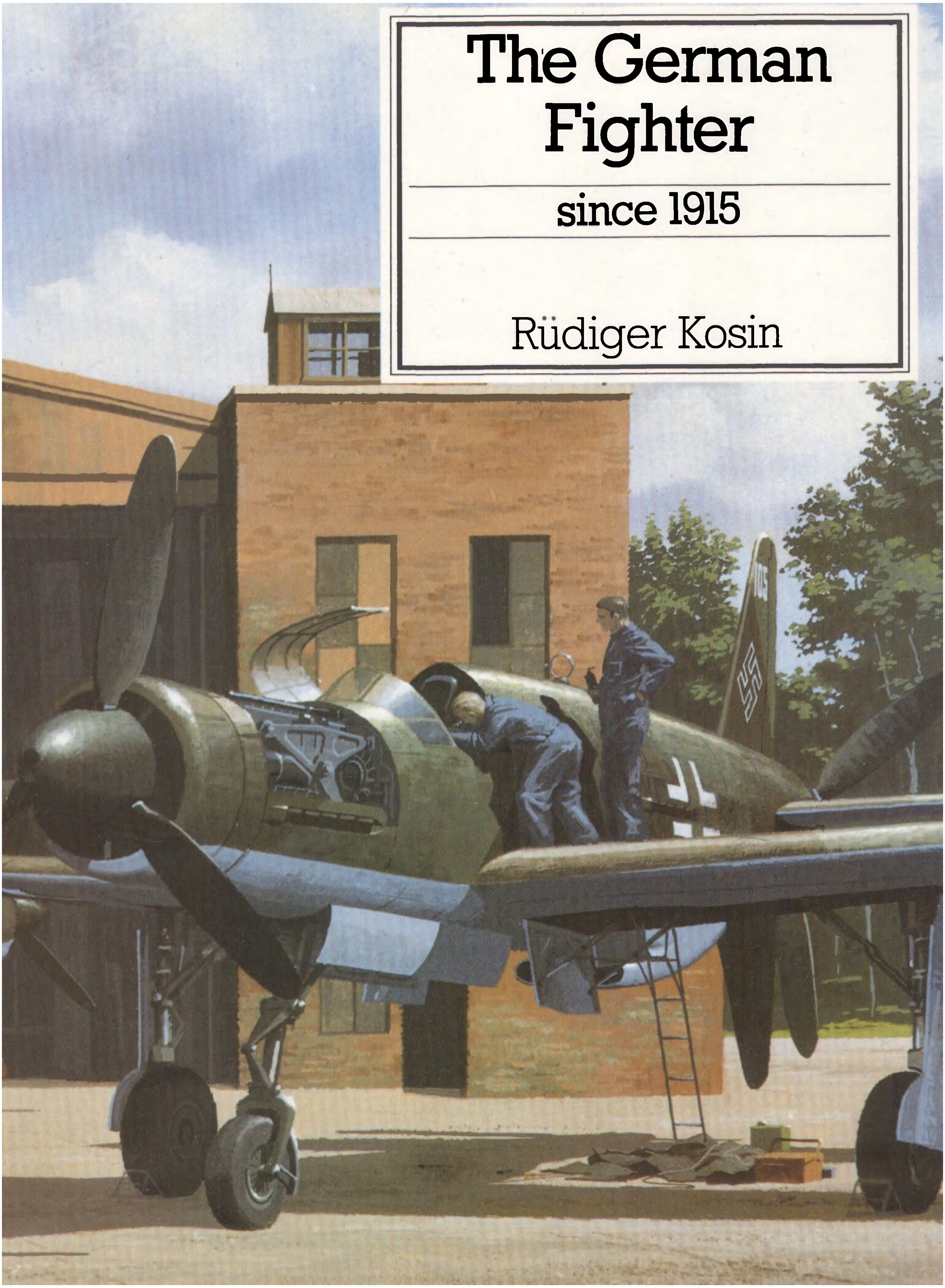
The German Fighter

since 1915

Rüdiger Kosin



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PUTNAM

Frontispiece: Perhaps the most famous of all German fighters, the Bf 109 in its -E form.

First English language edition published 1988 by Putnam, an imprint of Conway Maritime Press Ltd, 24 Bride Lane, Fleet Street, London EC4Y 8DR

ISBN 0 85177 822 4

First published in German as *Die Entwicklung der deutschen Jagdflugzeuge* by Bernard & Graefe Verlag, Koblenz 1983

Translated by Keith Thomas

Printed and bound in Great Britain at The University Printing House, Oxford

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Foreword

It is no simple matter to describe the development of German fighter aircraft. Of those military and industrial documents and drawings which survived two wars, many were looted, destroyed, or taken abroad as part of the spoils of war. Those remaining, and some which were later given back, were once more subjected to the scrutiny of souvenir hunters. It is almost a miracle that the documents which have survived — from private collections, and rescued museum and archive documents — have been found sufficient to assemble a comprehensive history of the German fighter.

The author's 60 years' activity in the aviation world have stood him in good stead for this project, but it would not have been possible without the generous support of others. First and foremost I owe a debt of gratitude to my wife, Barbara, for the patience with which she has tolerated my frequent absences — both mental and physical — and for her own work. She wrote the manuscript and all the correspondence, and that was no small undertaking.

My requests for permission to use pictures and documents have been answered in a friendly and helpful way by more than fifty individuals, often after considerable correspondence. I hope they will excuse me if I do not name them all, but I wish to acknowledge my sincere thanks to all of them here. A few of them I would like to mention in particular, for the great efforts they have made:

Flugbaumeister Dipl-Ing Gerhard Geike
General-Ing a.D. Dipl-Ing W. Hertel
Dipl-Ing Helmut Koch
Obering Hans Rebeski
Dipl-Ing Walter Zucker

The text is based exclusively on accredited documents, the author's own memory, and the memories of those personally involved, for whose credibility the author can vouch.

Performance figures are only stated where they are based on official documents; company figures have not been used. Names are only mentioned when absolutely necessary. The overall development of aviation is a great achievement of many minds working in concert. In commemoration of this I would like to dedicate this book to all those who have worked with me in the cause of aviation.

Rüdiger Kosin
Ottobrunn near Munich, January 1983

Introduction

The aircraft below is the original ancestor of the German fighter. Its direct descendant, influenced by a fleeting visit from a Frenchman*, was the Fokker E I — the first German single-seat fighter. If the observer, or more precisely the impartial observer, cares to compare it with the Messerschmitt Bf 109 (later the Me 109) — one of the last of the propeller-driven fighter aircraft — he will see that the differences are really not that great.

At the front is an airscrew, behind that the engine, with two machine-guns mounted above it. Aft of the engine are the wings, with the pilot next, located roughly in the centre of the enclosed fuselage. At the rear of the fuselage are the horizontal and vertical tail surfaces, and a tailskid or tailwheel; a two-wheel undercarriage is common to both. Although the Fokker E I inevitably looks somewhat fragile and imperfect in comparison with the Me 109, it may come as a surprise to many today that the two machines had virtually identical wingspan and tail lengths, as can be seen from the drawing on Page 12, which shows both aircraft to the same scale. The wing areas are also the same, at around 16 sq m.

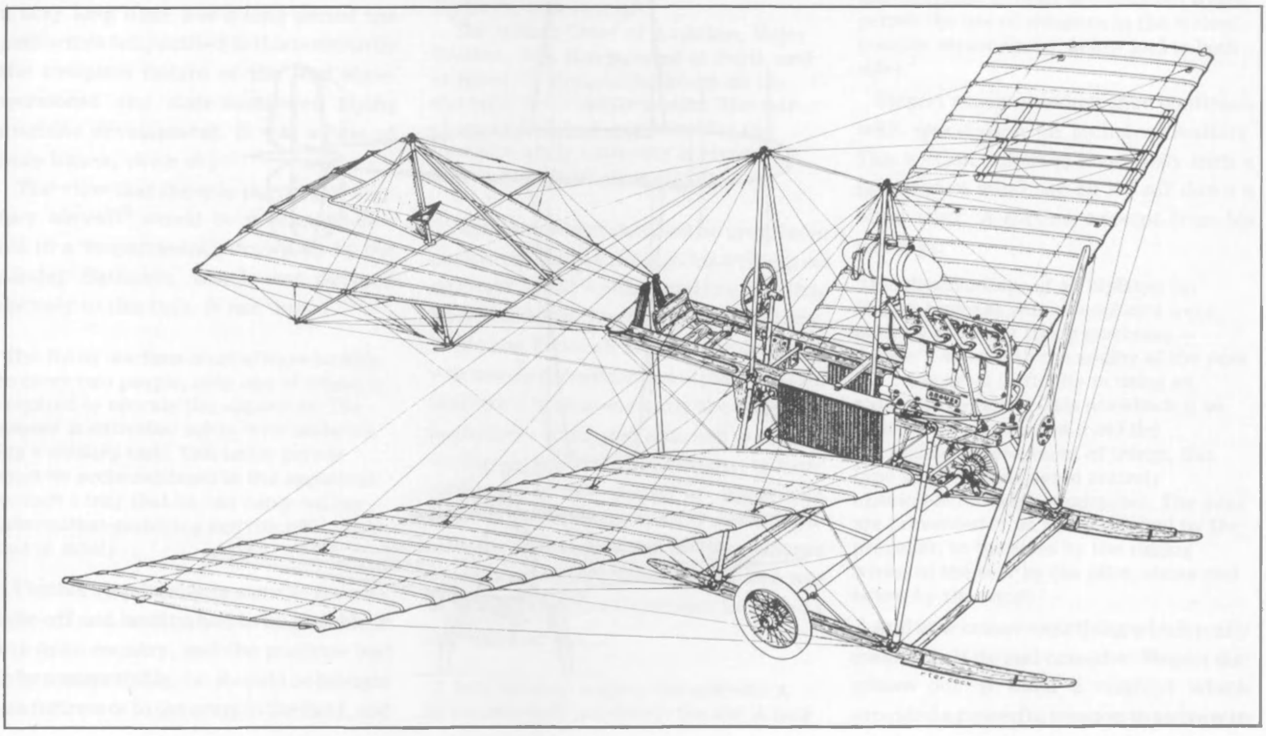
The two machines were separated by 20 years and by many major technological advances, but the gulf between them is actually far wider than it appears. Between the two designs innumerable other concepts were tried and found wanting, many blind alleys and false routes were tried, until designers eventually turned back to the simple, elegant concept which was the basis of this first German fighter.

The purpose of this book is to describe this complex process of development, to show how the idea of the fighter aircraft came into being, and how the idea matured.

In the author's opinion, his career in the aviation industry puts him in a particularly good position to explain some of what happened in the hectic period from 1933 to the end of the War. This information is presented in the first person, as the author's own experience, since, although it cannot be viewed as strictly documentary information, it results from his direct, personal involvement in the affairs of the time, and helps to convey an impression of the period. From the summer of 1933 the author took an active part in the development of aviation, following on from his initial training on gliders, and his years of activity in the Akademische Fliegergruppe (University Flying Group) during his period as a student. He had the good fortune to work on interesting projects during his industrial career as an aircraft construction manager, to be fully trained as a pilot, and to experience the early years of the build-up at Rechlin test centre. He was not the only engineer to develop an important role in aviation from his position as aircraft construction manager; the engineer pilots of the Arado, Dornier, Focke-Wulf, Heinkel and Messerschmitt companies all started in the same way, along with industrial and serv-

* This fleeting visit was the forcing down of a Morane-Saulnier Type N flown by Roland Garros. It was captured intact.

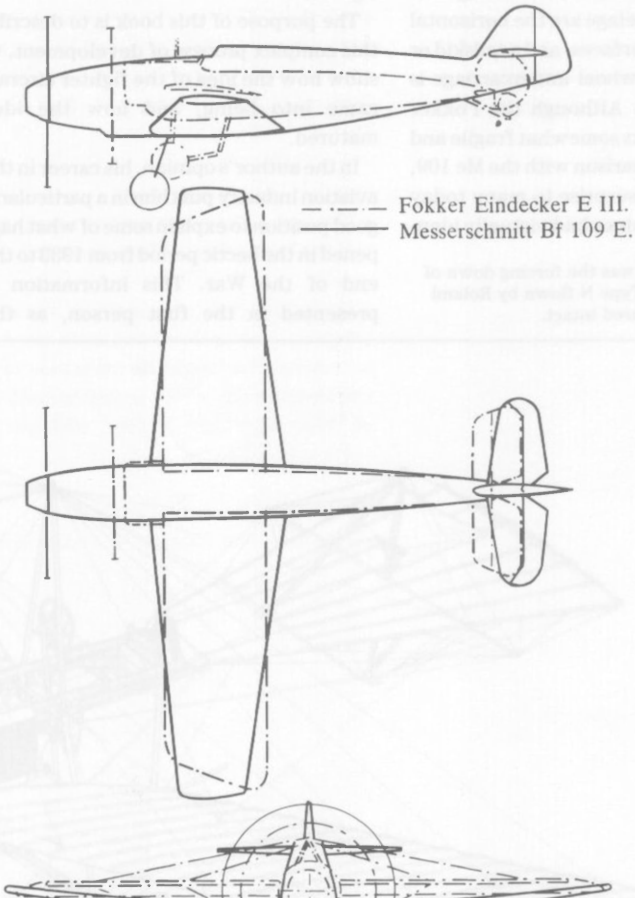
Fokker Spin (Spider) 1912.



ice engineers and leading experts in all departments of the Air Ministry.

Rechlin at the time was in the hands of a tightly knit group of individuals, which the author joined at just the right time. By coming into close personal contact with leaders from industry, research institutes and the future Luftwaffe, he was party to information and opinions which would not otherwise have been accorded to a young man in his mid-twenties. He has had direct access to all the documents presented in this book, in whole or in part, while working on it.

Above: Fokker fighter E I-E III 1915/16.



Below: Fokker E III and Messerschmitt Bf 109E to the same scale.

From the beginning to 1918

The Origins of Military Aviation

The Military's First Requirement: Reconnaissance

It was the imaginative Wright brothers, from Dayton, Ohio, who first succeeded in lifting a 'dynamic' flying machine from the ground and returning to it in a more or less reliable manner. Hardly had they succeeded in staying in the air for more than a few minutes, covering distances corresponding to a day's march or more, than the German General Staff and Airship Battalion began to examine the new invention for its military potential. The consensus — in Germany as in America — on the aircraft was that its role lay in monitoring the movements and position of the enemy, and for undertaking reconnaissance far behind enemy lines or behind fortifications, where patrols were unable to penetrate[1]. In spite of the 'flying machine's' evident good prospects the German authorities did not see fit to finance its development. It was to be left to private enterprise, and thus it was for a very long time. For a long period the authorities felt justified in this position by the complete failure of the first state-sponsored and state-monitored flying machine development. It was a case of once bitten, twice shy.

The view that the sole purpose of military aircraft[2] would be reconnaissance led to a 'requirement', drawn up by the Airship Battalion, which was devoted entirely to this task. It ran thus:

'The flying machine must always be able to carry two people, only one of whom is required to operate the apparatus. The second is entrusted solely with undertaking a military task. This latter person must be accommodated in the apparatus in such a way that he can carry out his information-gathering activity efficiently and in safety . . .'

Further requirements were as follows: take-off and landing had to be possible in any open country, and the machine had to be transportable, *i.e.* it could be brought to a fortress or to the army in the field, and assembled on site for use. Major Siegert of the General Staff wrote a memorandum dated 1 January, 1914, from which we will quote several times. One of its points was:

'The light, low-powered single-seater belongs in the field close to the General Command staff.'

In Siegert's view this aircraft could only be a single-seater 'which is child's play to fly'. He had seen several such machines, including the French Morane-Saulnier, the Grade-Eindecker (monoplane) and the Fokker Eindecker, which by this time had become very similar to the Morane. On the Morane aircraft Siegert's memorandum runs (abbreviated):

'At the Paris Aero Salon the firm of Morane-Saulnier exhibited a monoplane whose wing was set about the fuselage[3]. I saw two examples of the machine fly at Villacoublay and obtained the best possible impression. On both flights the machine carried an observer. Conditions for observation must be particularly favourable. Use of weapons is only restricted immediately forward of the pilot, in the cone-shaped sector dictated by the propeller diameter. Pilot forward, observer aft.

The Italian Chief of Aviation, Major Douhet, was also present at Paris, and ordered 24 Morane-Saulniers on the strength of its performance. The purchase of two test machines for the Prussian army authority is recommended without reservation.'

Douhet was later destined for great fame as General Douhet through his writings on strategic aerial wafare, and the fact that he ordered 24 aircraft for the Italian army, while the Prussian army administration was merely recommended to purchase two machines, indicates clearly the degree of importance which was attached to aircraft on the German side. In Germany, or more precisely in the upper or uppermost reaches of the German army administration, the views of Douhet had by no means been accepted. After the Italo-Turkish war in Tripolitania and Cyrenaica in 1911-12 he stated:

'A new weapon is born: the aircraft! A new battlefield is created: the air! A new chapter is opened in the history of warfare: the chapter of aerial war!'

Aircraft Armament — First Thoughts

Nevertheless, there were people — engineers, other individuals in industry, and even in the Services — who were thinking seriously about aspects of military aviation other than pure reconnaissance or observation.

Again the words of Major Siegert (slightly abbreviated):

'It will not be possible to operate without weapons. Every reconnaissance flight will result in an encounter with enemy aircraft. It is inconceivable that aircraft will attempt to ram each other. It is likely that an aircraft which is capable of shooting at an enemy machine will have the advantage, whether passing, approaching, retreating, overtaking, flying above or below, at a range of a few hundred metres.

The most suitable weapon is a light, air-cooled machine-gun. The army which succeeds in knocking the enemy's aerial reconnaissance system out of operation, with the help of firearms, will have the advantage. With these facts in mind, it is essential that aircraft are designed which permit the use of weapons in the widest possible sector above, below and to both sides.'

Siegert's memorandum then continues with speculation on technical matters. This section indicates how easily such a progressive mind can be led off down a blind alley. A further excerpt from his writings:

'One disadvantage of all biplanes (to Siegert biplanes and monoplanes were entirely different flying machines — *author's note*) with the engine at the nose is. . . the great difficulty in using an automatic weapon. This drawback is so serious, that bearing in mind the irresistible development of things, this type must be considered entirely unsuitable for combat purposes. The guns are prevented from firing forward by the propeller, to the sides by the rigging wires, to the rear by the pilot, above and below by the wings.'

And now comes something which really makes us sit up and consider. Siegert dismisses out of hand a concept which provided a powerful weapon to aircrew in

KAISERLICHES PATENTAMT.

PATENTSCHRIFT

№ 248601

KLASSE 77*h*. GRUPPE 5.

AUGUST EULER in FRANKFURT A. M.

Flugzeug mit Maschinengewehr.

Patentiert im Deutschen Reiche vom 24. Juli 1910 ab.

Die Erfindung hat den Einbau eines Maschinengewehres in ein Flugzeug zum Gegenstand und bezweckt, ohne besondere Visier- und Steuereinrichtung an dem Maschinengewehr selbst mit den Steuerungen des Flugzeuges das Zielen des Maschinengewehres zu bewirken.

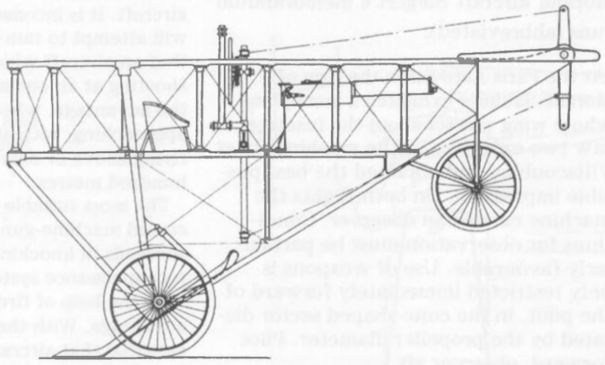
Auf der Zeichnung ist der Erfindungsgegenstand beispielsweise dargestellt. Das Maschinengewehr ist vor dem Führersitz fest in das Fahrgestell eingebaut, so daß der Lauf des Maschinengewehres unter dem Höhensteuer geradeaus durchgerichtet ist. Das Maschinengewehr ist so unter dem Hohensteuer eingebaut, daß die Kugel auf bestimmte mittlere Entfernung denjenigen Punkt treffen kann, welchen der Flugmaschinenfuhrer, über das Hohensteuer hinwegsehend, ins Auge faßt.

Die Breitensteuerung des Maschinengewehres wird in gleicher Weise durch die Seitensteuerung des Flugzeuges bedient.

Der Fuhrer hat also, indem er Seiten- und Hohensteuer des Flugzeuges bedient, gleichzeitig die Höhen- und Breitensteuerung des Maschinengewehres in der Hand und bedient beide gleichzeitig, wenn er mit dem Flugzeug auf den zu beschießenden Punkt zufliegt und gleichzeitig mit den Steuerungen des Flugzeuges über den Mittelpunkt des Höhensteuers, den Steuerhebel, zielt. Das Abdrucken des Maschinengewehres wird durch Auslösen der beiden kleinen Hebel am Maschinengewehr mittels der Füße besorgt. Der feste Einbau des Geschützes gerade vor dem Führersitz hat den Vorteil, daß die Lenkung des Flugzeuges und das Zielen durch den Fuhrer allein besorgt werden kann; außerdem fallt der Rückstoß genau in die Flugrichtung, so daß Kippmomente auf das labile Flugzeug vermieden werden.

PATENT-ANSPRUCH:

Flugzeug mit Maschinengewehr, dadurch gekennzeichnet, daß das Maschinengewehr mit seinem Rohr vor dem Führersitz fest in das Anfahrgestell eingebaut ist, so daß das Zielen lediglich durch die Hohen- und Seitensteuerung des Flugzeuges erfolgt und der Rückstoß stets in die Flugrichtung fallt.



Patent granted to August Euler for installation of a machine-gun in an aircraft.

later years, and was widely acknowledged as a great achievement. It was known about one whole year before the war:

'The idea of mounting a machine-gun within the propeller hub is an affectation, as is the alternative of coupling the firing mechanism to the propeller's rotation, which would make it possible to fire bullets between the propeller blades when they are in the correct position. The objection to mounting the gun barrel within the propeller hub is the same as to any gun position which is fixed along the longitudinal axis of the aircraft: the pilot is forced to fly directly at the enemy in order to fire. Under certain circumstances this is highly undesirable. With this form of gun installation any superiority in speed will be nullified when weapons are used'.

One can only wonder whether this memorandum, written by a man in a most influential position, whose only wish was to promote the aircraft as a flying weapon, did more harm than good. In spite of other opinions contained in it, such as:

'The whole matter proves once again that all experiments in aviation must be undertaken free of any influence which is rooted in prejudice, whether it is of an artillery or a technical infantry nature or anything else.' And:
'The more freedom in design the manufacturers are allowed, the better'.
And:
'The requirements for a combat aircraft must be settled soon.'

1910: Aiming with the Aircraft

The idea that it might not be possible to use firearms to put the enemy's aerial reconnaissance out of action, without flying directly towards the enemy, had not been considered by the military. However, engineers had been thinking along these lines for years, even before aeroplanes could fly properly.

August Euler, who had built one of the first powered aircraft in Germany, and was himself a pilot, patented an invention (No. 248 601) through the Imperial Patent Office, whose purpose was 'the installation of a machine-gun in an aircraft, the aiming of the machine-gun being effected by means of the aircraft's controls, without the use of special sighting and control arrangements on the machine-gun itself.'

Here we have the classic fighter aircraft concept, described on 24 July, 1910, five years before the first fighter aircraft existed in Germany. Euler's aircraft had a lattice tail arrangement with rear-mounted engine, *i.e.* the propeller could not obstruct the gun. But by 1914 the lattice tail had been abandoned almost entirely by aircraft designers; it had been very popular in France and Britain, but never in Germany. By this time something approaching a military aircraft concept was beginning to develop. A typical example was the Albatros B II biplane, designed in 1913, which became the pattern for countless variations on the theme. If we compare the structure of this aircraft with that of the Pfalz D XII, which was successful in the fighter aircraft competition held in summer 1918, then we cannot help wondering why the route from the one to the other was so protracted and difficult.

1913: Aircraft Armament before the start of the War

Franz Schneider, at that time technical director of the LVG (Luft-Verkehrs Gesellschaft), was so convinced of the correctness of this concept, that he came upon the most unusual idea of arming these aircraft with a fixed weapon firing forward. His first idea, worked out in conjunction with Daimler, was for the propellers to be driven by a gearbox outside the crankcase, so that a machine-gun could shoot through the hollow propeller shaft. This idea, patented by Daimler Motoren-Gesellschaft on 11 January, 1913, (Patent No. 290 120), was known as the 'Kanonenmotor', or cannon engine. The result was a four-cylinder engine built by Daimler. It is certain that the technical difficulties involved in adding an external gearbox to a four-cylinder engine, with insufficient flywheel mass, would have inevitably caused structural failure, not to mention the lubrication problems. The idea first came to fruition in the eight-cylinder V-motor made by Hispano-Suiza, built during the First World War. It was designed to accept one 37 mm cannon, but it did not see active service. However, most of the German twelve-cylinder engines of the Second World War were of the 'Kanonenmotor' type.

Albatros B II, 1914.

Pfalz D XII fighter, 1918.

Schneider's insistence on the necessity of firing forwards, and of the correctness of the 'coachman behind the horses' principle, subsequently led to the invention which was later adopted on all fighter aircraft, friend and foe. It was patented on 15 July, 1913, under No.276396:

'The basis of the invention is a mechanism which permits a gun to fire between the propeller blades, without damaging them. To this end the gun is mounted immediately in front of the pilot and behind the propeller. In order to avoid damage to the propeller, a blocking mechanism is fitted to the trigger. This mechanism is rotated constantly by the propeller shaft, and blocks the gun's trigger at the moment when the propeller blade is located in front of the muzzle. In consequence the weapon can only be fired between the propeller blades.'

Despite this mental preparation for armed military aircraft, neither the weapons nor the aircraft were ready in time for the war, and the Military Aviation Service was completely unprepared for armed combat in the air at the outbreak of hostilities. A letter from the 'Idflieg' (Inspektion der Fliegertruppe — Flying Corps Inspectorate — set up in October 1913) is reproduced on page 17.

The reconnaissance aircraft at the Western Front, whose great importance had been recognised, were very soon driven out of the air almost entirely by enemy aircraft. These were armed, fighter aircraft — the first in history.

These first fighter aircraft embodied one version of the principle behind Euler's patent of 1910, *i.e.* a fixed, forward-trained machine-gun was aimed by the control movements of the aircraft itself. The Morane-Saulnier monoplane could even fire through the propeller disc, although it did not use the principle of synchronised propeller and machine-gun, as patented by Franz Schneider. Instead bullets which did not pass between the propeller blades ricocheted off armour plates on the blades. However, when a Morane monoplane was obliged to land behind the German lines, its propeller, or more precisely the propeller's armour, failed under test with a German machine-gun, as the German steel-cased bullets penetrated the armour.

A Lesson from the French: Firing through the Propeller

The armoured French propeller fell into German hands on 19 April, 1915, but it was five weeks before tests were made on it. An excerpt from a report by the Bavarian liaison officer seconded to the Royal Prussian technical transport testing committee, dated 16 May, 1915:

'According to a telephone report just received from the I.d. Flieg, interesting tests on guns fired from monoplanes will take place on Wednesday 19th May p.m. or Thursday 20th May a.m. (through the propeller; a French invention, which came to our knowledge after the capture of the pilot Garros).

The I.d. Flieg has asked me to suggest that an officer stationed in the region and also the director of the Pfalz aircraft works should take part in the Imperial inspection, as the staff officers of the 6th Army pilots are to propose that parasol monoplanes be equipped with the appropriate mechanism.'

On 31 may, 1915, the Bavarian War Ministry heard that the

'tests (mentioned in the previous letter) with firing through the propeller have not taken place, according to a telephone message from the aviation department. The arming of at least some of our aircraft with machine-guns is without doubt an urgent necessity; as Prussia has

DEUTSCHES REICH

REICHSPATENTAMT

PATENTSCHRIFT

№ 290120

KLASSE 77h GRUPPE 5

Daimler-Motoren-Gesellschaft in Stuttgart-Unterturkheim.

Durch Propeller angetriebenes Luftfahrzeug mit als Vorgelegewelle ausgebildeter hohler Propellerwelle.

Patentiert im Deutschen Reiche vom 11. Januar 1913 ab.

Vorliegende Erfindung betrifft ein durch Propeller angetriebenes Luftfahrzeug (Ballon oder Flugmaschine), welches mit einem Geschütz versehen ist, das derart angeordnet ist, daß es möglich ist, ohne durch den Propeller behindert zu werden, in der Richtung der Propellerachse zu schießen. Das Fahrzeug ist in an sich bekannter Weise mit einem Motor versehen, dessen hohle Propellerwelle als Vorgelegewelle ausgebildet ist. In der hohlen Welle ist nach vorliegender Erfindung das Geschütz angeordnet. Es ist hierdurch möglich, gewissermaßen durch den Propeller hindurchzuschießen, ohne daß derselbe stört. Die lichte Weite der hohlen Propellerwelle wird zweckmäßig so groß gewählt, daß der durch die Welle hindurchgeführte Geschützlauf in der Querrichtung gegen die Welle verstellt werden kann, um ein Richten des Geschützes zu ermöglichen.

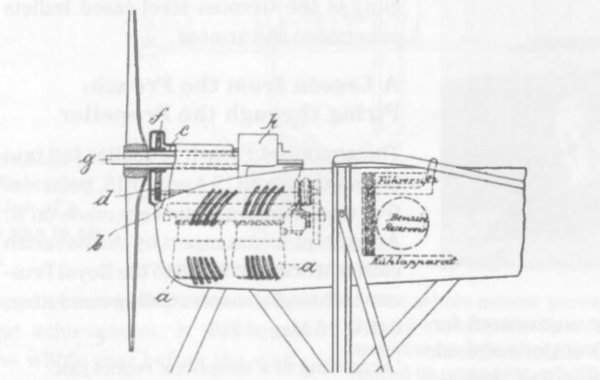
Auf der Zeichnung ist ein Ausführungsbeispiel der den Gegenstand der Erfindung bildenden Anordnung dargestellt.

Der Motor ist in bekannter Weise mit nach unten gerichteten Zylindern *a* in das Gestell einer Flugmaschine eingebaut und treibt durch seine bei dieser Anordnung oben liegende Kurbelwelle *b* die über dieser liegende Propellerwelle *c* mit Hilfe der Zahnräder *d* und *f* an. Die Propellerwelle *c* ist hohl ausgebildet und durch dieselbe der Lauf *g* eines Geschützes irgendwelcher Art hindurchgeführt. Hinter der hinteren Lagerung der hohlen Vorgelegewelle *c* befindet sich der Verschluß *h* des Geschützes. Das Geschütz kann als Maschinengewehr oder in irgendeiner anderen geeigneten Weise ausgebildet sein, und die Anordnung kann an sich eine beliebige sein. Das Wesentliche liegt darin, daß das Geschütz so angeordnet ist, daß das Geschoß durch die hohle Propellerwelle hindurchbefördert wird. Bei einer solchen Anordnung kann der Propeller entweder vorn oder hinten sich befinden.

PATENT-ANSPRÜCHE:

1. Durch Propeller angetriebenes Luftfahrzeug mit als Vorgelegewelle ausgebildeter hohler Propellerwelle, dadurch gekennzeichnet, daß in der Propellerwelle ein Geschütz beliebiger Art angeordnet ist.

2. Luftfahrzeug nach Anspruch 1, dadurch gekennzeichnet, daß die lichte Weite der hohlen Propellerwelle so groß gewählt ist, daß der durch die Welle hindurchgeführte Geschützlauf zum Richten des Geschützes in der Querrichtung gegen die Welle verstellt werden kann.



KAISERLICHES PATENTAMT.

PATENTSCHRIFT

№ 276396

KLASSE 77h. GRUPPE 5.

FRANZ SCHNEIDER IN JOHANNISTHAL B. BERLIN.

Abfeuerungsvorrichtung für Schußwaffen auf Flugzeugen.

Patentiert im Deutschen Reiche vom 15. Juli 1913 ab.

Gegenstand der Erfindung ist eine Vorrichtung zur Ermöglichung des Schießens zwischen den Propellerflügeln hindurch, ohne sie zu verletzen. Zu diesem Zweck ist die Schußwaffe unmittelbar vor dem Führer und hinter dem Propeller angebracht, und zwar kann dieselbe innerhalb bestimmter Grenzen drehbar angeordnet sein.

Um nun eine Schädigung des Propellers zu verhindern, ist ein Sperrmechanismus für den Abzug vorgesehen. Diese Sperrvorrichtung wird von der Propellerwelle aus beim Fahren fortwährend in Umdrehung versetzt und sperrt den Abzug der Schußwaffe immer in dem Augenblick, wo sich einer der Propellerflügel vor der Mündung der Schußwaffe befindet. Demnach kann das Abfeuern der Waffe nur zwischen den Propellerflügeln hindurch stattfinden.

Auf der Zeichnung ist ein Ausführungsbeispiel der Erfindung dargestellt.

Fig. 1 stellt den Vorderteil des Flugzeugs in Seitenansicht dar, während

Fig. 2 eine Ansicht der Sperrkurvenscheibe veranschaulicht.

Die im vorliegenden Falle als Gewehr ausgebildete Schußwaffe ist in irgendeiner geeigneten Weise vorteilhaft auf einem am Motor befestigten Lager angebracht und kann innerhalb bestimmter Grenzen seitlich und nach oben und unten gedreht werden. Hinter den Abzug der Waffe greift ein in einem festen Lager *f* drehbarer Hebel *e*, dessen unteres Ende sich gegen eine Kurvenscheibe *d* (siehe Fig. 2) legt. Diese Kurvenscheibe wird von der Propellerwelle *a* aus mittels konischer Zahnräder *b* und der senkrechten Welle *c* angetrieben und ist so gestaltet, daß sie den Hebel *e* so lange gegen den Abzug drückt, als sich ein Flügel des Propellers vor der Gewehrmündung befindet. In dem Augenblick, wo die Propellerflügel an der Mündung vorbeigegangen sind, kann die Schußwaffe abgefeuert werden.

Es ist selbstverständlich, daß die Sperrung des Abzugs noch in mancherlei anderer Weise erfolgen kann und die Erfindung keineswegs auf die beschriebene Anordnung beschränkt ist.

PATENT-ANSPRÜCHE:

1. Abfeuerungsvorrichtung für Schußwaffen auf Flugzeugen, gekennzeichnet durch eine Sperrvorrichtung für den Abzug der hinter der Bewegungsbahn der Propellerflügel liegenden Schußwaffe, welche durch eine von der Propellerwelle angetriebene Vorrichtung mit dem Abzug in Eingriff gehalten wird, solange ein Propellerflügel sich vor der Mündung der Schußwaffe befindet.

2. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Vorrichtung aus einer von der Propellerwelle aus angetriebenen Kurvenscheibe (*d*) besteht, die den Abzug der Schußwaffe mittels eines Sperrhebels (*e*) so lange verhindert, als ein Propellerflügel sich vor der Mündung der Schußwaffe befindet.

Fig. 1

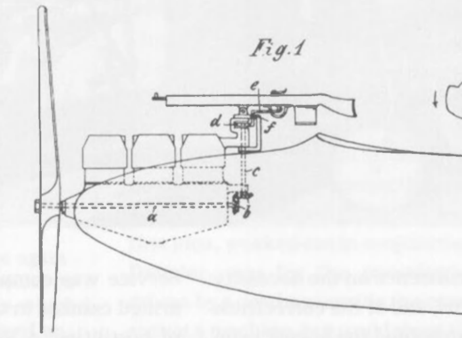
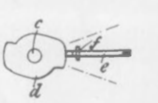


Fig. 2



apparently had no success to date in this regard, the Pfalz parasol aircraft is probably suitable, and hence tests using this aircraft can only be advantageous. Initially to A II for comment on whether a machine-gun can be handed over.'

It appears from this that the rate of armament was relatively slow, and development work was split between different sites; it is also likely that communications between the various agencies, at least between Bavaria and Prussia, were not as good as they might have been.

Patent granted to Daimler Motoren Gesellschaft for a cannon motor, 1913.

Patent granted to Schneider concerning firing a gun through the propeller arc, 1913.

The Building of the First Fighter Aircraft

The Light Monoplane

Yet by the spring of 1915 the Prussian and Bavarian armies had finally accepted the concept of fighter aircraft, since a letter dated 22 April, 1915, from the Bavarian War Ministry stated:

'their biplanes are no match for the French lightweight monoplanes.'

The fundamental threat was the Morane-Saulnier monoplane. What could be more appropriate then, than to try the Fokker and Pfalz monoplanes, which were similar or identical to the French aircraft? Pfalz had obtained a licence from Morane in 1913, and Fokker based his M.5 aircraft very closely on the same machine, albeit

with some important modifications.

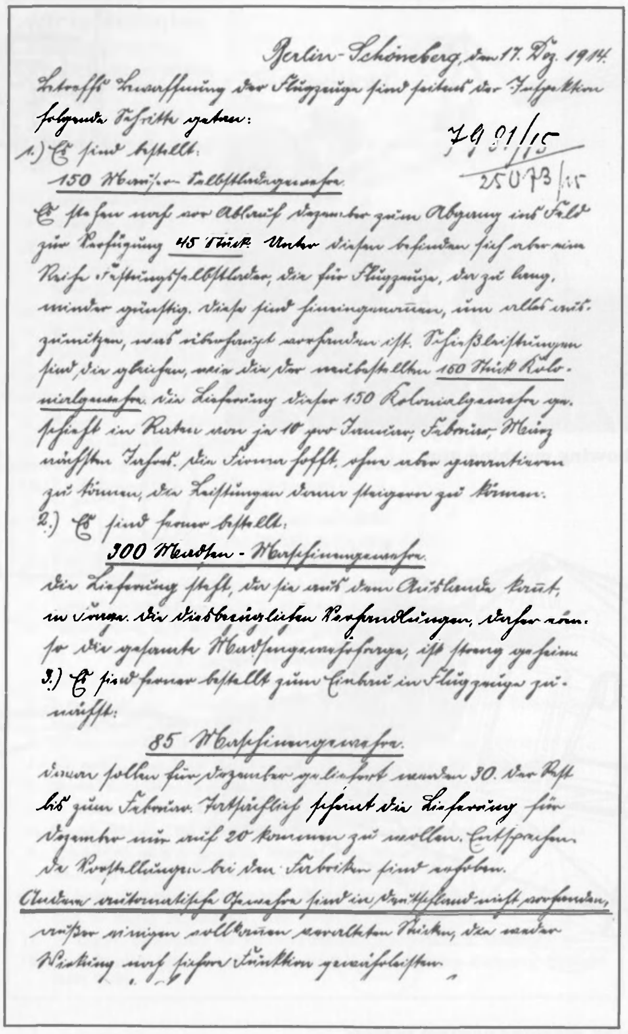
Platz, who was technical director at Fokker for nearly two decades, chose to adopt a steel-tube framework for the fuselage in place of the usual wooden structure; his design methods were to remain standard on fighter aircraft up to 1940. A new wing section was also used, with a deeper rear spar. It did not prove possible to introduce these aircraft in large numbers in a short space of time because of supply problems with machine-guns and engines. The 'light monoplanes' were fitted with Oberursel 80 hp rotary engines, but the entire production of these in June 1915 was only 25-26 units. The prospects for obtaining machine-guns looked even worse. The request for one machine-gun for an experimental installation, as already mentioned, received the following reply from A II.

'The demand for machine-guns for the Front is so great that we are nowhere near meeting it . .'

It was clear, then, that some time would necessarily elapse before it would be possible to set up a fighter aircraft force.

Initially the air divisions were each allotted just two aircraft for defence of their unit and the aerodrome, aircraft which were no more than armed, lightweight, close-range reconnaissance machines. On 1 August, 1915, Immelmann shot down his first enemy opponent, while defending his air division's base. His Fokker E I had a fixed machine-gun mounted at the front, synchronised with the propeller. The history of the German fighter aircraft could be said to begin at this point.

These first fighter monoplanes were fitted with the 80 hp Oberursel UO rotary



Berlin-Schöneberg, den 17. Dez. 1914.

79 81/15
25073/15

Betrifft: Bewaffnung der Flugzeuge sind seitens der Inspektion folgende Schritte getan:

1.) Es sind bestellt:

150 Mauser-Selbstladegewehre.

Es stehen noch vor Ablauf Dezember zum Abgang ins Feld zur Verfügung 45 Stück. Unter diesen befinden sich aber eine Reihe Infanterie-Selbstlader, die für Flugzeuge, da zu lang, minder günstig. Diese sind hinausgegangen, um alles auszunützen, was überhaupt vorhanden ist. Schießleistungen sind die gleichen, wie die der weiterbestellten 150 Stück Kolonialgewehre. Die Lieferung dieser 150 Kolonialgewehre geschieht in Raten von je 10 pro Januar, Februar, März nächsten Jahres. Die Firma hofft, ohne aber garantieren zu können, die Leistungen dann steigern zu können.

2.) Es sind ferner bestellt:

300 Madsen-Maschinengewehre.

Die Lieferung steht, da sie mit dem Auslande kreuzt, in Frage. Die diesbezüglichen Verhandlungen, daher [illegible] für die gesamte Maschinengewehrfrage, ist streng geheim.

3.) Es sind ferner bestellt zum Einbau in Flugzeuge zunächst:

85 Maschinengewehre.

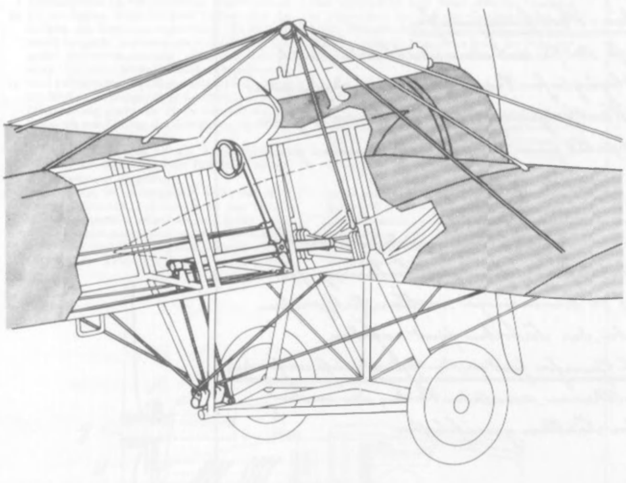
Davon sollen für Dezember geliefert werden 30. Der Rest bis zum Februar. Tatsächlich scheint die Lieferung für Dezember nur auf 20 kommen zu wollen. Entsprechende Bestellungen bei den Fabriken sind erfolgt.

Andere automatische Gewehre sind in Deutschland nicht vorhanden, außer einigen wenigen veralteten Stücken, deren Wirkung nach hiesiger Ansicht zweifelhaft.

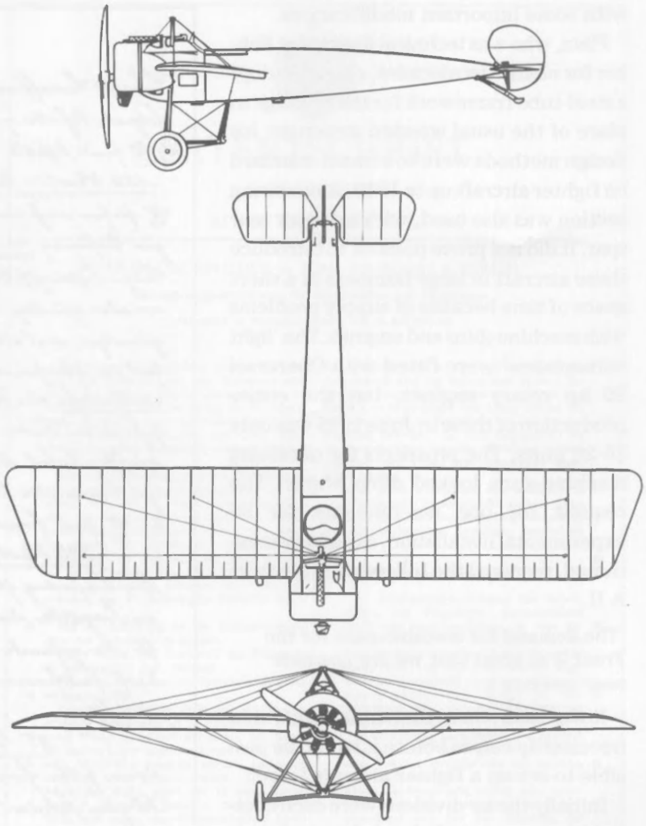
Measures to be taken for arming aircraft, December 1914.

Fokker Eindecker (monoplane).

Fokker Eindecker, showing machine-gun.



Fokker Eindecker, wing warping control system.



Fokker E III

Wingspan	9.5 m
Length	7.2 m
Wing area	15.5 sq m
All-up weight	610 kg
Oberursel U I	100 hp

motor, an air-cooled seven-cylinder radial engine. In this type of engine the crankshaft is fixed, while the cylinders, crankcase and all the rest of the machinery rotate round it. It was a French design built under licence by the Oberursel engine factory; the licence had been obtained before the war. By adding two further cylinders the Oberursel UO was developed into the nine-cylinder U I, producing 100 hp. The Fokker E II was virtually identical to the E I apart from the new engine. Eventually it was superseded by the Fokker E III, which incorporated strengthening which had proved to be necessary.

At the Pfalz works, where a licence to build the French Morane-Saulnier type L had been obtained, the company's parasol monoplane underwent a similar course of development.

One technical peculiarity of both aircraft was the method of lateral control using wing warping, instead of the ailerons commonly used on biplanes. The front spar of the wing was braced in a fixed position to inverted V-struts above the fuselage and V-struts in line with the undercarriage. The rear spar bracing cables on the underside of the wing ran to a rocker mounted at the apex of a V-strut mounted horizontally below the fuselage. The rocker was rotated to left or right by the control column, via cables. The corresponding cables on the upper surface of the wing were connected to each other via a pulley, with the result that, when the stick was moved to the left, the port wing was twisted to negative incidence and the starboard wing to positive. This was an extremely simple and effective system which was aimed at fulfilling the requirement for ease of rigging and de-rigging.

These first fighters were armed with the Parabellum shoulder machine-gun (sMG), which was manufactured by the German Waffen- und Munitionsfabriken (German Arms and Munitions Company), formerly Ludwig Loewe. It was converted from water-cooling to air-cooling by cutting slots in the cooling mantle.

At the same time — June 1915 — experiments aimed at converting the MG 08 machine-gun were also in progress.

As the air-cooled MG 08 gun became available, it was installed to an increasing degree in aircraft. After conversion the weapon was designated the IMG 08/15, but was usually known simply as the 'Spandau' outside Germany. Eventually 08/15 became the jargon term for 'standardised'.

Synchronised Firing through the Propeller

Although the idea of synchronising the machine-gun with the propeller shaft may sound simple, in practice it proved anything but. The firing rate of the machine-gun is fundamentally constant, and if the propeller speed is constant, each bullet passes through the propeller plane at the same point between the blades. However,

if motor speed alters, the point between the blades begins to shift. Production tolerances in ammunition and the temperature of the bullets could also result in further movement of the firing point relative to the propeller, and occasionally a bullet would strike a blade. Initially the fighters were fitted with a single machine-gun only. A second gun proved to be an urgent necessity, both to increase the intensity of fire and to allow for frequent jamming. It is known that one Fokker Eindecker was fitted with three guns, but for a long time the number of weapons was restricted to one because of the bottleneck in machine-gun supply.

Unfortunately there had been no option but to pick aircraft with rotary engines to be the first fighters. These motors were really only intended for light observation aircraft; only small numbers had been considered necessary, and it had been planned to cease production early in 1915. The aircraft's merits — ease of de-rigging and transport — were no longer of great importance now that the war had become bogged down. A report dated 14 May, 1915, includes the following statement:

'The Fokker Eindeckers in existence are still flown, but there will be no new orders'.

Thus no preparations had been made for manufacturing rotary engines in large quantities.

In any case the main focus of the Idflieg in the development of aircraft power plants had been the water-cooled inline engine. The criterion by which the Imperial competition for aircraft engines was judged was the total weight of the power plant and fuel for seven hours at constant speed, *i.e.* more importance was placed on specific fuel consumption than on engine weight. In consequence, if more power was required for the fighter aircraft, few suitable engines were available. And an improvement in performance was an urgent requirement. After the first fright about the 'Fokker scourge' the allies had soon settled down, and brought their own new, higher-performance aircraft into the fray. These were primarily biplanes. What could be more appropriate, then, than to return to biplanes?

The German Aircraft Industry in 1914

At this point we will interrupt the history of the German fighter aircraft for a moment, and take a look at the German aircraft industry.

Kriegsministerium.

Luftfahrt-Abteilung.

Zentrale fur Flugzeug-Industrie.

Nachweisung

der

hauptsachlichsten Flugzeugfirmen, die fur Heereslieferungen in Betracht kommen.

A. Flugzeug-Fabriken.

1. Luftverkehrs Gesellschaft, A. G., Berlin Johannisthal.
2. Allgemeine Elektrizitäts-Gesellschaft, Flugtechnische Abteilung, Hennigsdorf b. Berlin.
3. Albatros Werke G. m. b. H., Johannisthal b. Berlin.
4. Emil Jeannin, Flugzeugbau, Berlin-Johannisthal.
5. Automobil- und Aviatik A. G., z. Zt. Freiburg i. Br
6. E. Rumpler, Luftfahrzeugbau G. m. b. H., Berlin-Johannisthal.
7. Deutsche Flugzeugwerke, Lindenthal b. Leipzig.
8. Euler Werke, Frankfurt a. M., Niederrad.
9. Gothaer Waggonfabrik A. G. Abteilung II, Flugzeugwerke, Gotha.
10. Fokker Aeroplanbau, Schwerin i. Meckl.
11. Flugzeugbau Friedrichshafen G. m. b. H., Friedrichshafen am Bodensee.
12. Deutsche Bristolwerke, Halberstadt.
13. Luftfahrzeug Gesellschaft m. b. H., Berlin W. 62, Kleiststr. 8.
14. Ago-Flugzeugwerke G. m. b. H., Johannisthal.

B. Flugmotoren-Fabriken.

1. Motorenfabrik Oberursel A. G., Oberursel b. Frankfurt a. M.
2. Daimler-Motoren Gesellschaft, Untertürkheim.
3. Benz & Co., Rheinische Automobil- und Motorenfabrik A. G., Mannheim.
4. Argus Motoren Gesellschaft m. b. H., Reinickendorf Ost, Flottenstr. 39/40.
5. Motorenbau G. m. b. H., Friedrichshafen am Bodensee.

C. Fabriken für Ersatz- und Zubehörteile.

1. Heine Propeller-Werke, Waidmannslust b. Berlin.
2. Franz Reschke vorm. Julius Meyer G. m. b. H., Präzisions Holzwaren und Propeller-Fabrik, Berlin SO. 36, Kottbuser Ufer 7.
3. Flugzeugwerke Richard Goetze Kommandit-Gesellschaft, Berlin SO. 36, Elsenstr. 106/7.
4. Maximall Apparate-Fabrik Paul Willmann G. m. b. H., Berlin SW., Blücherstr. 12.
5. Richard Reske, Klempnerei und Apparatebau, Neukolln, Bergstr. 132.
6. O. Trinks, Spezialfabrik fur Flugzeugteile, Berlin, Lindenstr. 101/2.
7. Garuda, Flugzeug und Propellerbau G. m. b. H., Neukolln, Naumburger Str. 42/43.
8. Metallgießerei Richard Musculus, Berlin SO. 36, Wiener Str. 18.
9. Nürnberger Schraubenfabrik und Facondreherei, Nürnberg.
10. J. Kinkel, Klempnerei und Apparatebau, Berlin SO. 33, Cuvrystr. 16.
11. Gust. Fr. Richter, Metallschraubenwerke, Berlin S., Sebastianstr. 12.
12. F. Wagner, Spezialfabrik fur Auto-Aero-Material, Reinickendorf-Ost, Frühlingstr. 16.
13. Hans Windhoff, Apparate- und Maschinenfabrik G. m. b. H., Berlin-Schöneberg, Bennigienstraße 21/22.

List of recognised German aircraft and accessory companies in 1914.

In October 1914 the war ministry recorded fourteen aircraft companies, five engine companies and thirteen companies producing replacement parts and accessories. These figures apply only to Prussia, although this is not expressly stated in the document. Bavaria, which had its own war ministry, was home to the Otto aircraft works in Munich, the Pfalz aircraft works in Speyer and the Rapp motor works in Munich. Of these firms no fewer than ten were engaged in building B and C aircraft in 1915. These were mostly private-venture designs, but they were so similar that it takes a trained eye to distinguish the types. They were two-bay biplanes, *i.e.* there were two pairs of struts on each side. The spaces between the struts were braced with diagonal cables. These 1914-15 aircraft had a wingspan of about 12 to 13 m and a wing area of around 40 sq m. If we reduce such a machine to half size according to the rules of aircraft design, *i.e.* reducing the linear dimensions by 70 per cent (square root of one half = 70 per cent) the result is a machine with a wingspan of 8.5-9 m and around 20 sq m wing area. An aircraft of approximately this size, powered by a 120 hp Benz engine, had been built as a 'racing biplane' in 1913 by the Albatros company; apparently the military had no time for it, perhaps because it was neither a 'light monoplane' nor a 'military biplane'.

The Successors to the Light Monoplane

The Biplane Era: Braced Biplanes

The Fokker Eindecker E III, of which around 260 had been built, was soon facing increasingly superior enemy aircraft. A further development, the E IV, powered by the 160 hp fourteen-cylinder UR III engine, was not a success; the gyroscopic forces of the engine were excessive, and in consequence there were problems with the aircraft's flying characteristics. The engine also proved to be unreliable. The E III was now to be replaced by a biplane.

Fokker tackled the problem in a manner typical of the man. He built four different machines, two single-bay and two two-bay biplanes, one of each with a water-cooled engine, one with an air-cooled engine. Practice took precedence over theory. To our modern ways of thinking there was rather too much testing and too little study. The pressure was on to produce something better in no time at all; manufacturers worried about missing the deadline or being beaten to the post by the competition; there was probably not much time left for studying. The results were the Fokker D I biplane with water-cooled engine, and the D II, which had the same power plant as the Eindecker E III.

A higher top speed was claimed for the D II, but it is difficult to believe this, for although the undercarriage was much simpler than that of the Eindecker, the struts and rigging wires of the biplane far outweighed this advantage. In consequence a higher-performance version was immediately demanded. The only option was the fourteen-cylinder UR III. The outcome was the Fokker D III, but the results of the conversion were just as disappointing as when the E III was converted into the E IV. The D II and D III were virtually identical in all other respects. In later years they were termed the A and B versions. As on the preceding monoplanes, lateral control was by wing warping, or twisting the flexible wings, as in the Wright brothers' aircraft from the first years of aviation.

In all, 340 units of both types were built. At the time they were ordered there was probably nothing better. However, something better soon came along: the Halberstadt D II with the 120 hp Daimler D II water-cooled engine. Although also a two-bay biplane, the aircraft must have had lower drag and thus offered a higher top speed. Fewer wires were located in the airstream, and the drag of a well faired inline engine with a reasonably well integrated radiator is far lower than that of a rotary unit. The wing structure was also fundamentally stiffer, which contributed to good aileron response, and the Halberstadt D II was fitted with proper ailerons instead of the Fokker's wing warping. The following is an extract from a report on the 'Halberstadter with 120 bhp Mercedes' dated 21 July, 1916:

'This aircraft has flown with great success at the Front, and pilots have expressed a high opinion of it in respect of climb performance and manoeuvrability. It is certainly preferable to the Fokker with 160 bhp, but in all cases a second machine-gun is an urgent requirement.'

There followed a series of aircraft of this order of size. The only points which remained unsettled were the power plant — rotary or fixed, *i.e.* air- or water-cooled — and the wing bracing — single-bay or two-bay. In fact no clear preference in either matter became evident right up to 1918. The choice of engine depended on the results of development testing, and on the quantities industry was able to supply. The number of struts remained a matter of taste. All of them were wire braced.

Over the next three years more than a hundred variants on the braced biplane theme reached the stage of flight testing. Those that survived testing were built in numbers of 20 or more for further examination; only about 30 designs reached this stage, and only about a dozen of these braced biplane fighter types saw active service at the Front.

The final choice amongst this dozen was often determined by the capacity of the individual factory, the availability of labour, and the engine supply situation.

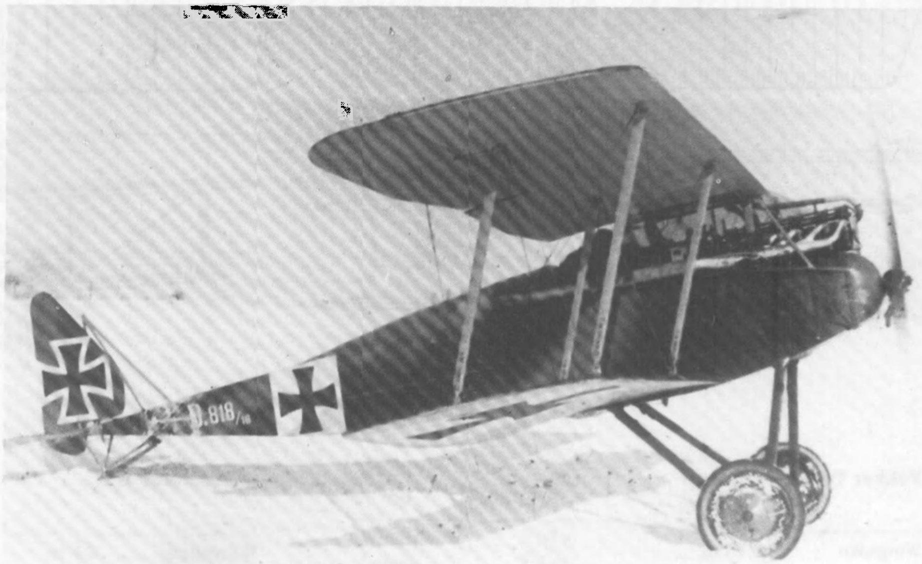
Very soon afterwards the first Albatros

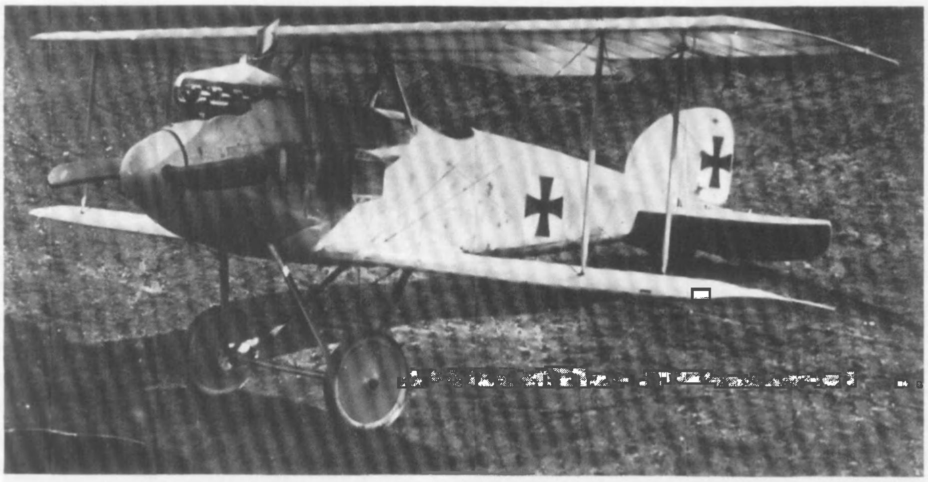
Albatros 'racing' biplane built for the Vienna flying week, 1914.

Fokker D I.

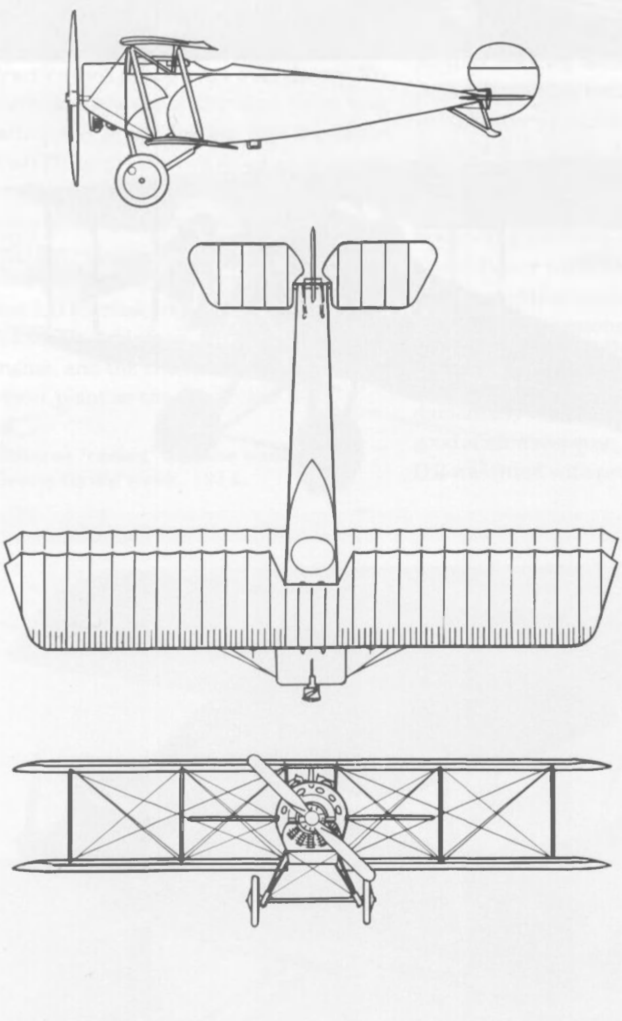
Fokker D II.

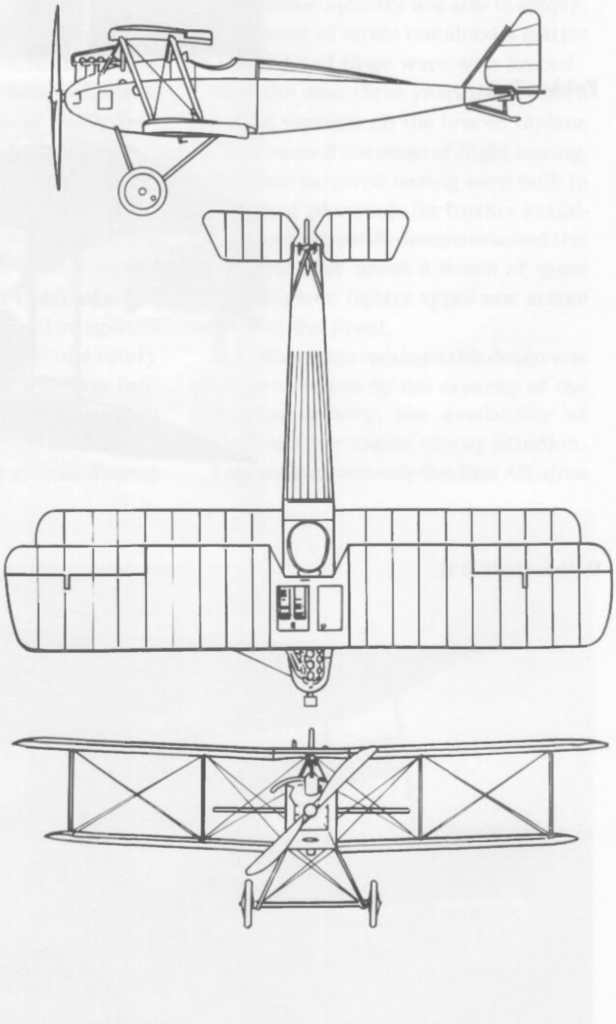
Halberstadt D II.





Albatros D I.





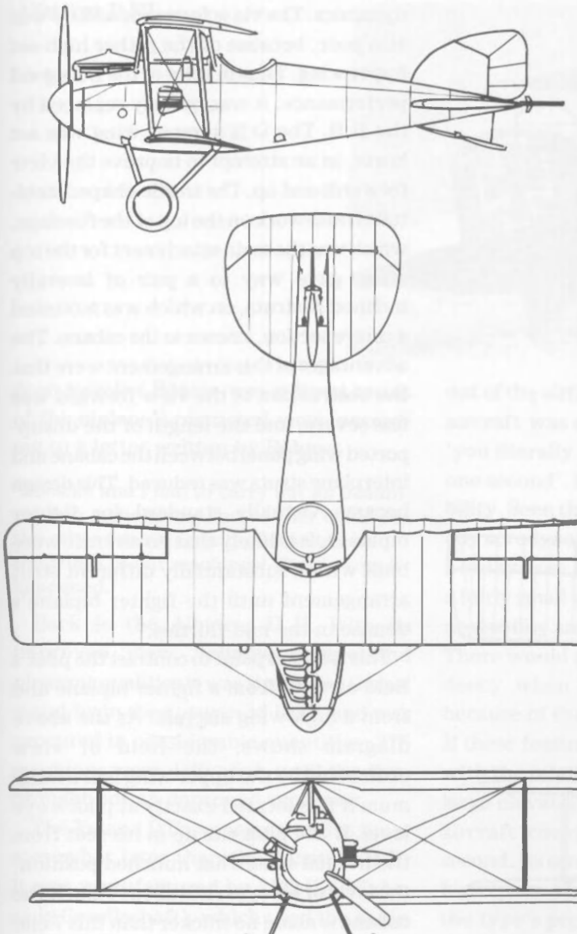
Fokker D II

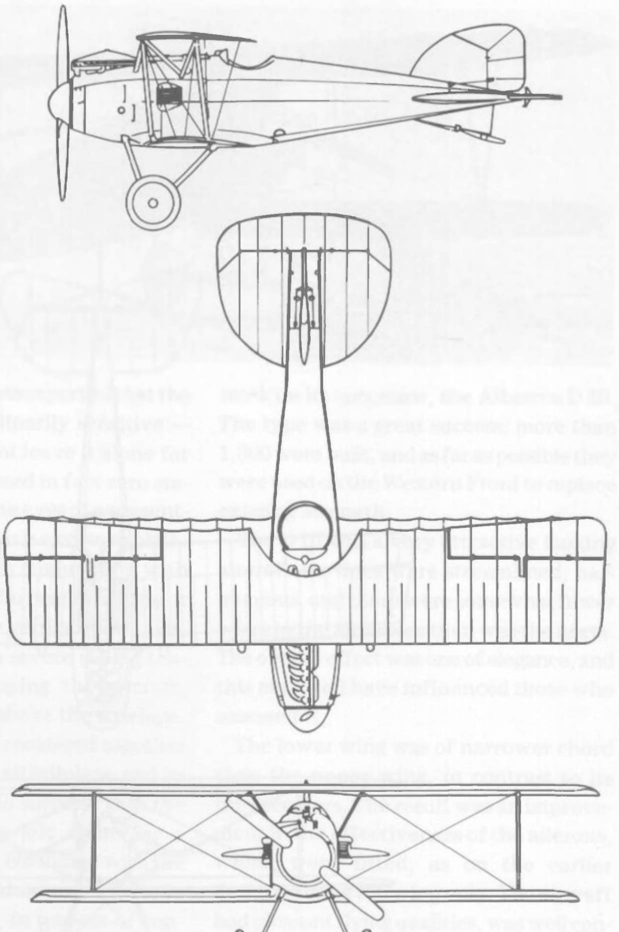
Wingspan	8.75 m
Length	6.4 m
Wing area	18.0 sq m
All-up weight	580 kg
Oberursel U I	100 hp

Halberstadt D II

Wingspan	8.8 m
Length	7.3 m
Wing area	24.0 sq m
All-up weight	770 kg
Daimler D II	110 hp

Albatros D II.



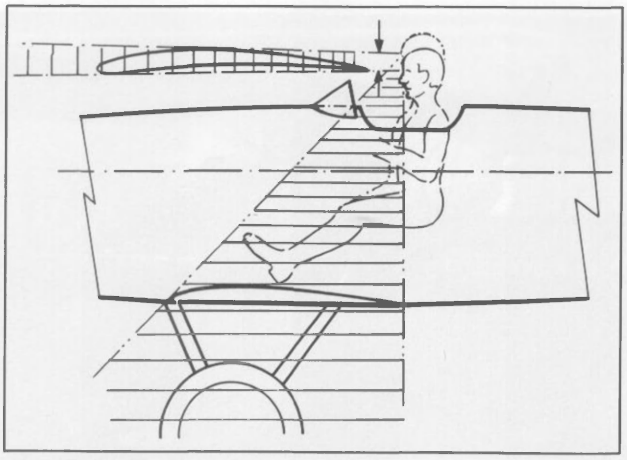


Albatros D I

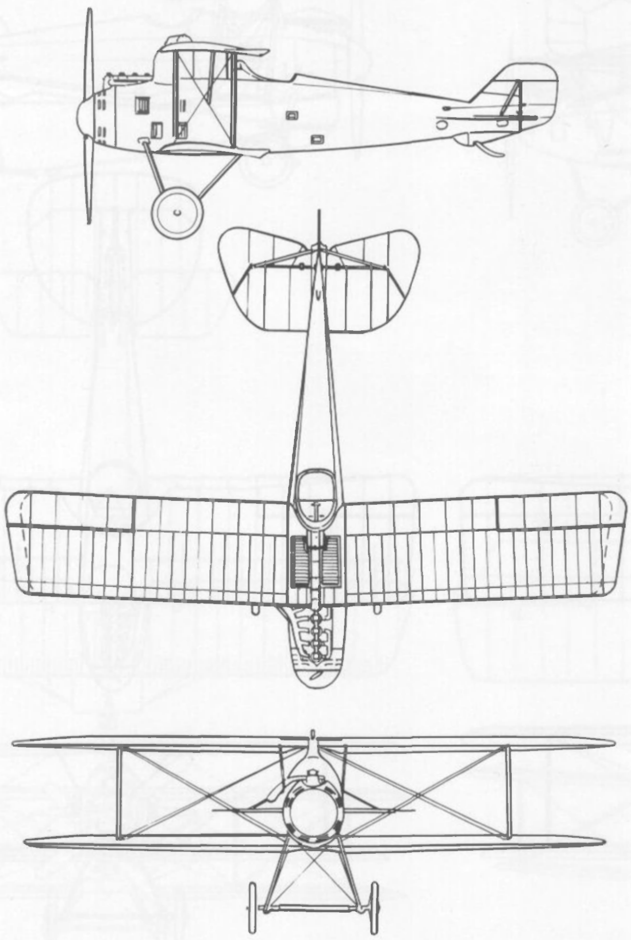
Wingspan	8.5 m
Length	7.4 m
Wing area	23.0 sq m
All-up weight	900 kg
Benz Bz III	150 hp

Albatros D II

Wingspan	9.05 m
Length	7.4 m
Wing area	24.5 sq m
All-up weight	890 kg
Daimler D III	160 hp



Pilot's view from a biplane.



LFG Roland D IIa

Wingspan	8.9 m
Length	6.95 m
Wing area	22.0 sq m
All-up weight	850 kg
Argus As III	180 hp

fighter appeared: the D I with the 150 hp Benz Bz III or the 160 hp Daimler D III engine. This aircraft was a single-bay biplane, and was markedly similar in design to the 'racing biplane' dating from 1913, mentioned earlier. Albatros aircraft up to that time had featured a plywood-skinned, box-section fuselage, but the D I had a smoothly rounded plywood shell structure, which endowed the aircraft with an extremely attractive appearance.

However, the designers could find nothing better to do with the radiator than allow it to stick out of the side of the fuselage, without any attempt at fairing it, thereby ruining the view obliquely downward, not to mention the aerodynamics. The view forwards and up was also poor, because of the rather high-set upper wing. Thus in spite of the D I's good performance, it was quickly replaced by the D II. The D II's upper wing was set lower, in an attempt to improve the view forwards and up. The trestle-shaped steel-tube framework on the top of the fuselage, which was the main attachment for the top wing, gave way to a pair of laterally inclined N-struts, on which was mounted a centre section, known as the cabane. The advantages of this arrangement were that the obstruction to the view forward was less severe, and the length of the unsupported wing panel between the cabane and interplane struts was reduced. This design became virtually standard for fighter biplanes. It is likely that no aircraft were built with a substantially different strut arrangement until the fighter biplane's demise in the mid-thirties.

This is a good point to contrast the pilot's field of view from a fighter biplane and from a high-wing aircraft. As the above diagram shows, the field of view obstructed by the upper wing is at a minimum if it is located exactly at pilot's eye level. If the pilot sits up in his seat from the normal somewhat hunched position, the level of his eyes rises about 7 cm. If the cabane is made no thicker than this 7 cm, the pilot has an unrestricted view over the entire forward field above and below the wing, without effort and without altering the aircraft's attitude. If the pilot's eye-point is below the wing, the wing on the inside of the turn severely obstructs the view forwards on the inside of the turn, and in this case the advantage of a wing set at pilot's eye level is much more pronounced.

Certainly Boelcke's crash on 28 October, 1916, after colliding with his fellow squa-

Roland D IIa.

Albatros D III.

dron member Bohme was a direct result of the biplane's restricted view, according to a letter written by Böhme:

'Boelcke and I had to carry out an instant evasion manoeuvre, and neither could see the other for a moment, obstructed by the wings of our machines. That is how it happened.'

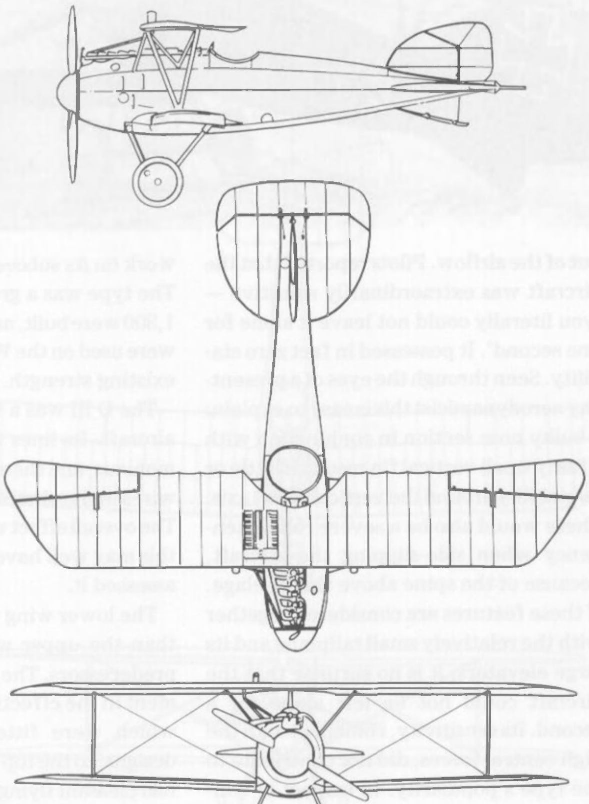
Back to the Albatros D II. With its improved view, reliable engine and pleasant qualities it was the Flying Corps' stand-by in the autumn of 1916, and was procured in considerable quantities; 275 machines were delivered, until the firm brought out an improved successor.

The Roland D IIa appeared at this time, somewhat later than the Albatros D II. It was manufactured by LFG (LuftFahrzeug Gesellschaft), which used the name of Roland for its products. The aircraft was virtually identical to the Albatros D II in size and weight, but was fitted with the 170 hp Argus AS III engine instead of the 160 hp Daimler D III. The pilot's eyepoint in relation to the upper wing was similar, although the narrow spine rising out of the fuselage, to which the upper wing was attached, slightly obstructed the view forwards. On the other hand the hoses to the radiator, which was integrated into the upper wing, were inside this spine and thus out of the airflow. Pilots reported that the aircraft was extraordinarily sensitive — 'you literally could not leave it alone for one second'. It possessed in fact zero stability. Seen through the eyes of a present-day aerodynamicist this is easy to explain: a bulky nose section in conjunction with a fairly small vertical fin results in little or no stability around the vertical (yaw) axis. There would also be a severe rolling tendency when side-slipping the aircraft, because of the spine above the fuselage. If these features are considered together with the relatively small tailplane and its large elevators, it is no surprise that the aircraft could not be left alone for a second. Its sensitivity, combined with the high control forces, did not contribute to the type's popularity. In respect of construction the Roland D IIa was very similar to the Albatros D II. Fabric-covered two-spar wings with wood spars and ribs, steel-tube struts between the spars, and diagonal wire bracing. The ailerons of the Roland D IIa were considerably smaller than those of the Albatros D II, and were fitted to the top wing only. About 150 examples of this type were built.

After developing the Albatros D II, which was little more than a refinement of the D I, Albatros immediately began work on its successor, the Albatros D III. The type was a great success; more than 1,300 were built, and as far as possible they were used on the Western Front to replace existing strength.

The D III was a very attractive looking aircraft. Its lines were streamlined, harmonious, and there were somewhat fewer wires in the airstream than was the norm. The overall effect was one of elegance, and this may well have influenced those who assessed it.

The lower wing was of narrower chord than the upper wing, in contrast to its predecessors. The result was an improvement in the effectiveness of the ailerons, which were fitted, as on the earlier designs, to the top wing only. The aircraft had pleasant flying qualities, was well constructed, and took into account the experience of pilots at the Front. For example, the radiator was located on the right-hand side of the cabane, so that, if the radiator were hit by a bullet, the pilot would not be subjected to the flow of hot cooling water as it escaped. Unfortunately the aircraft had one serious fault: it could not be dived without restraint. Pilots were warned of this: in a steep glide, the lower wing twisted and began to flutter, followed by the upper wing. Flutter, and



Albatros D III

Wingspan	9.05 m
Length	7.4 m
Wing area	20.5 sq m
All-up weight	900 kg
Daimler D III	160 hp

undamped torsional oscillation of the wing which could also lead to bending oscillations, occurs when an aircraft exceeds a certain speed, and the phenomenon was one of the aircraft designer's greatest headaches right until the late 'thirties. It is unlikely that the reasons for this behaviour in the Albatros D III were understood at the time. Two features of the aircraft which were probably added to improve the machine's appearance can now be seen to be fundamentally incorrect in aerodynamic terms, and could have been put right quite simply: first, the rearward curve of the wingtips, and second the single-spar construction of the lower wing, which could not provide sufficient torsional rigidity. Nevertheless the Albatros D III was the best aircraft at the Front throughout the winter of 1916-17 – and far into the summer. Manfred von Richthofen achieved most of his 80 victories flying the D III. In the meantime the LFG company had reworked its Roland D IIa; the lower wing was reduced in size and the spine wing attachment was replaced by four stubs projecting out of the fuselage. The aircraft remained unchanged in other respects, and after a short period of action the type disappeared from the Western Front. It seems that the essential reinforcements had increased the weight by too much, and it may also be that the flying characteristics had not been improved.

In the early summer of 1917 a new Pfalz biplane flew for the first time: the D III with the 160 hp Daimler D III engine. It proved to be a success right from the start. Until that time Pfalz aircraft had by no means had a glorious history. Just like Fokker, the Pfalz aircraft works converted a light reconnaissance monoplane, built under licence from the French firm of Morane-Saulnier, into an armed combat aeroplane, but had apparently not attempted to incorporate any improvements. On 25 March, 1916, the firm was informed by the Flying Corps Inspectorate that it

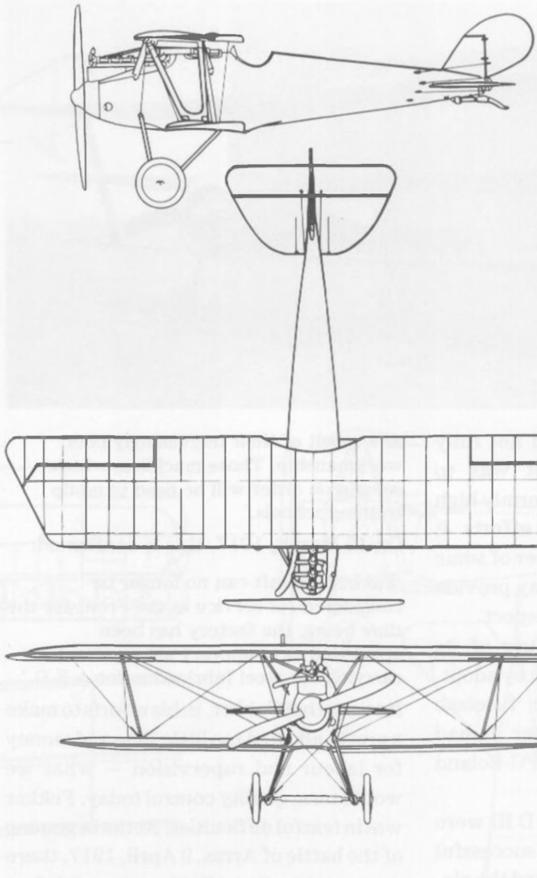
'must produce a monoplane with better flying characteristics, as there can be no justification for installing the small number of Oberurseler motors available in aircraft with poor flying performance and handling, thus denying engines to aircraft with better performance.'

This report was conveyed by the Bavarian liaison officer at the Idflieg on 21 July, 1916; he added:

'We suggested and discussed the construction of a D-aircraft. It is likely

Pfalz D IIIa

Wingspan	9.4 m
Length	7.4 m
Wing area	22.0 sq m
All-up weight	935 kg
Daimler D IIIa	180 hp



Pfalz D III.

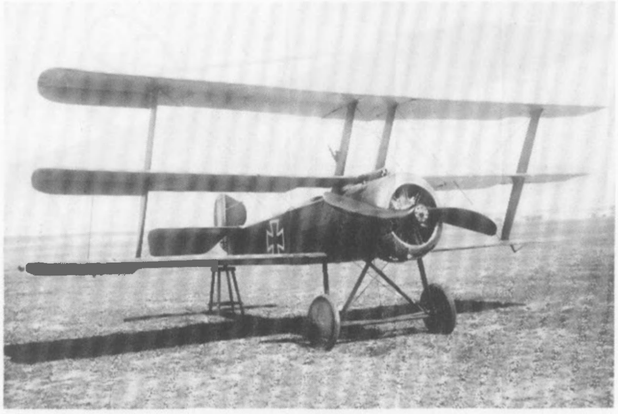
that we shall soon order the firm to cease production.'

After a series of fatal accidents all Pfalz aircraft were withdrawn from the Front and scrapped. It is said that the factory was threatened with closure, but that the decision was reversed on 17 August, 1916. On 8 September, 1916, Pfalz was awarded a licence to build LFG Roland aircraft, to exploit the factory's experience in wood construction. The contract was for 20 machines, which were known as the Pfalz D I.

The reproof of the Bavarian Pfalz works seems to have had no serious ramifications, probably because the fault lay with one company, rather than with the military authorities. However, about six months later, on 3 March, 1917, the Kogenluft — Air Commander General — sent a telegraphic complaint from Headquarters to the Bavarian War Ministry about deficiencies in construction quality at the Bavarian Albatros aircraft factory, and demanded that the Bavarian supervisors, like those of all other Federal States, should be made subject to the Idflieg, which carried sole responsibility. 'Otherwise I shall be forced to close down the company altogether. I request that you telegraph your agreement.' Two days later the Bavarian authorities acknowledged receipt of the telegram, but this time the Bavarian lion was not content to cower.

The Royal Bavarian military plenipotentiary intervened, informing the Kogenluft and his chief of staff: 'we are always willing to consider suggestions, but not in the categorical and dictatorial terms which perhaps you are accustomed to using when dealing with the Prussian K.M.'

It is evident that many of those at the



Sopwith Triplane, captured in the summer of 1917.

higher levels of command did not fully understand how difficult it was to manufacture machines to uniformly high standards, and what great efforts it required at this time. The career of some Fokker products of this era may provide some enlightenment in this respect.

The Pfalz company made use of its experience with Roland aircraft by adopting the wooden monocoque fuselage design for its new D III fighter. It had apparently first been used by LFG-Roland as early as 1915 for a C-type.

The dimensions of the Pfalz D III were very close to those of the successful Albatros D III. Although it lacked the elegant lines of the Albatros, it managed to avoid the structural design errors detailed earlier; whether this was intentional or not is not known. The trailing edge of the ailerons was not swept back, and the bottom wing had two spars, with a bracing cable running to the outboard trailing edge of the upper wing, which largely eliminated the twisting tendency. In other respects the aircraft was as carefully designed aerodynamically as could be expected for a wire-braced biplane dating from 1917. The junction between lower wing and fuselage, a particularly difficult problem with a rounded fuselage, was faired in very effectively. According to a report dated 9 July, 1917, 'the Pfalz D III can be considered the equal of the Albatros D V in performance. It will be ready for service this month.'

Of a total order of 525 D-type aircraft for the month, 300 were Pfalz D IIIs and only 200 Albatros D IIIs. From this time on the Pfalz D III played a major role in the (Bavarian) front-line units.

For a long period nothing was heard of Fokker aircraft. On 6 December, 1916, the Idflieg reported:

'Fokker aircraft are henceforth prohibited from use at the Front, mainly as a result of their increasingly poor workmanship. Those machines which remain on order will be used to equip training schools.'

On 15 March, 1917, this is confirmed:

'Fokker aircraft can no longer be considered for service at the Front for the time being; the factory has been appointed as temporary sub-contractor carrying out steel fabrication for A.E.G.'

It seems that Fokker, in his efforts to make a profit, allowed too little time and money for labour and supervision — what we would term quality control today. Fokker was in fearful difficulties. At the beginning of the battle of Arras, 9 April, 1917, there were practically no Fokker aircraft left at the Front. That is a measure of how fast things were moving.

The Triplane

In the battle of Arras the British Sopwith Triplane, fitted with the Clerget rotary engine, was brought into service for the first time. Richthofen first encountered one on 20 April, 1917. He brought the machine to Fokker's attention during one of his visits to the Front.

Fokker was always welcome at the Front. He was a masterful pilot, and counted as a 'member of the club'. Pilots could speak to an expert and know that he understood. Pilots always love talking to aircraft design engineers, as they can be sure that their experiences and complaints will be heard and understood at the highest level.

Fokker set to without delay to develop a triplane. It was a completely independent design, since no captured Sopwith Triplane was available.

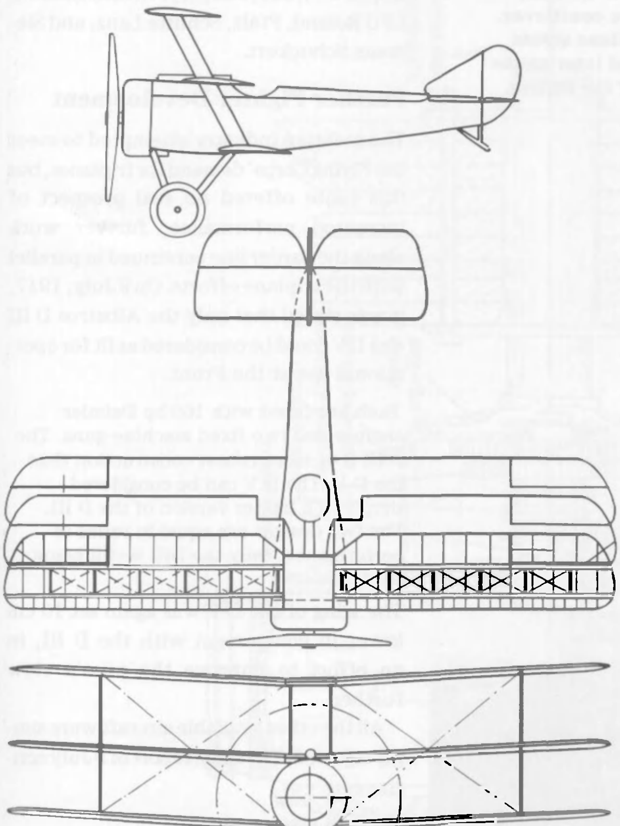
The first experimental Fokker triplane had three identical cantilever wings, each built in one piece. The lower wing was flush with the bottom of the fuselage, the centre wing flush with the top of the fuselage and the upper wing spaced equally above that, supported by two inverted V-struts. Ailerons were fitted to the top wing only, in contrast to the Sopwith Triplane, which had short ailerons on all three wings. The fabric-covered wing was of wood construction, with a 12.5 per cent thick section, but it was completely unorthodox in design. At the one-third chord point there were two box spars 55mm wide, connected by a plywood band top and bottom, resulting in a 20 cm wide box structure with considerable torsional rigidity. The front part of the wing was skinned with plywood in the interests of aerofoil fidelity, but the skin was not connected to the spar, and thus did not contribute to overall torsional stiffness.

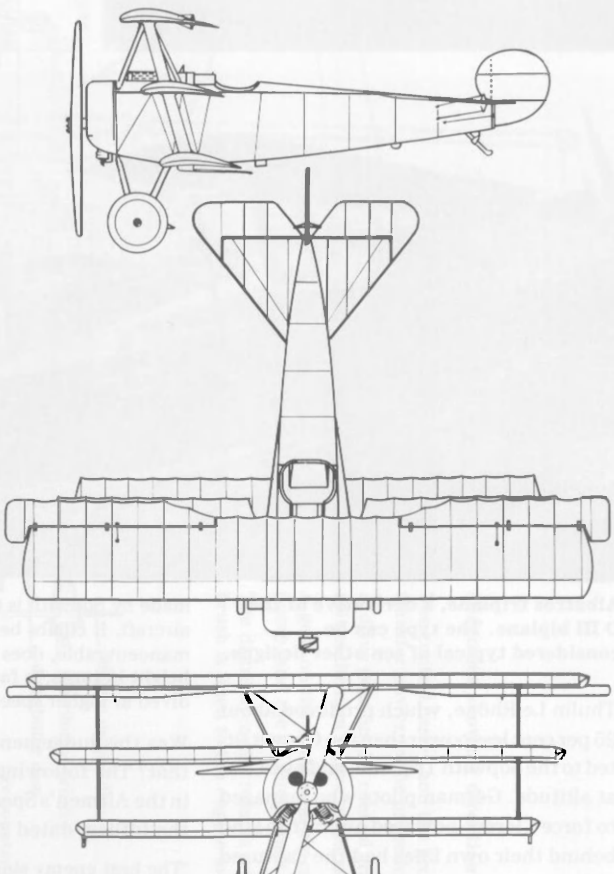
The fuselage was based on a steel-tube framework in the Fokker style, with diagonal wire bracing. The tail surfaces were also built out of thin-walled steel tubing and fabric-covered, just like the fuselage. The undercarriage consisted of two V legs, as was now standard on all aircraft. An innovation here was the link between the undercarriage legs, formed as a box inside which the rubber-sprung axle could move. The box had an aerofoil section fairing, which was intended to contribute to overall lift and reduce drag.

While Fokker was making encouraging test flights, Germany was hit by an outbreak of triplane fever. Almost every factory which was concerned with aircraft leapt — or was forced to leap — upon the triplane bandwagon. On 27 July, 1917, the aircraft companies were shown a captured Sopwith Triplane, but even before that Pfalz and Siemens had been granted a contract to build three triplanes each. But Fokker had a lead of perhaps two months. On 9 July, the day when the Idflieg awarded the contracts to Pfalz and Siemens, we learn that:

'the Fokker Dr I Dreidecker (triplane), pronounced Dre 1, with 110 hp Le Rhone engine, represents the first practical triplane. It is said to be capable of reaching 5,000 m in 18 minutes. There is an obstacle to series production in so far as insufficient Le Rhône motors are available for installation.'

What is meant here is evidently the high-compression version. The advantage of the Fokker concept was that the aircraft was very small and light, and that a number of engines were available, ordered earlier from the Swedish firm of Thulin. The engines were delivered, but were now in store, after air-cooled engines had been superseded generally by water-cooled inline units for fighter aircraft.





Sopwith Triplane

Wingspan	8.05 m
Length	5.5 m
Wing area	23 sq m
All-up weight	700 kg
Clerget	130 hp

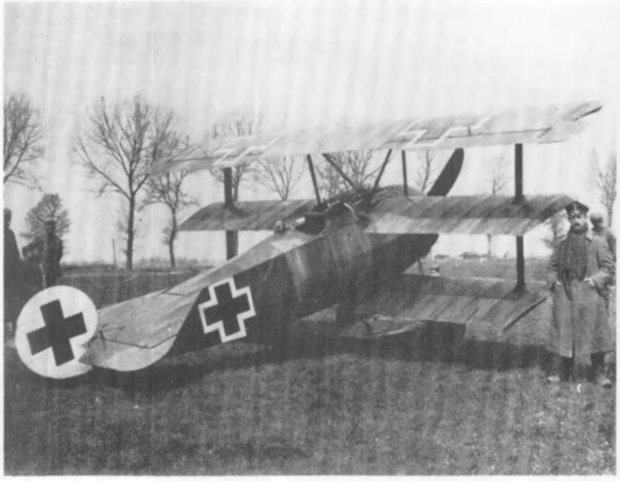
A few modifications were necessary – wings of slightly increasing span from bottom to top, installation of wing struts to reduce the tendency for the wings to vibrate, aerodynamic balances on ailerons and elevators to reduce the control forces – then the aircraft was ready for type approval. On 29 August the Fokker 'Dr I has passed the strength test. The first 20 machines can be expected in the next few days.'

The aircraft first saw active service at the Front on 30 August, and on 1 September Manfred von Richthofen achieved his first 'kill' – his 60th overall – from a triplane. But soon the Fokker disease set in once more. At the end of October several machines disintegrated during aerial combat as a result of poor workmanship. All Dr I machines were grounded, and Fokker had to supply replacements at his own cost. Six months later, at the end of March 1918, production had already ended. A new star was rising, again a Fokker: this time the D VII.

In the meantime the search had continued for a superior triplane. The Fokker triplane was indeed outstandingly manoeuvrable, but the low power of its engine meant that its speed and performance at altitude were not quite good enough, and for a variety of reasons all experiments with alternative power plants had met with failure. Thus the only unit which could be used remained the 110 hp

Fokker Dr I

Wingspan	7.2 m
Length	5.8 m
Wing area	19 sq m
All-up weight	590 kg
Oberursel U II	110 hp



Fokker Dr I. Initially the wings were centilever. The interplane struts were added later at the demand of the Idflieg.

Albatros triplane, a derivative of the D III biplane. The type can be considered typical of ten other designs.

Thulin Le Rhône, which produced about 25 per cent less power than the Clerget fitted to the Sopwith Triplane, and even less at altitude. German pilots who managed to force Clerget-powered aircraft to land behind their own lines had the captured engine built into their own triplane. Manfred von Richthofen is said to have used a Clerget.

At least 20 triplanes were built in the period between summer 1917 and summer 1918. Many of them were conversions of existing biplanes; real bodged jobs, and they looked it.

It is not easy to establish what the driving force was behind the great triplane race. A long treatise on the subject 'Triplanes versus biplanes' printed in the Technical Reports of the Berlin-Adlershof Aircraft Institute dating from 1917 ends with these words:

'According to Cavalry Captain Baron von Richthofen the captured English triplane made by Sopwith is the enemy's best aircraft. It climbs better, is more manoeuvrable, does not lose so much height in turns, is faster, and can be dived at higher speed'.

Was this judgement as influential as all that? The following statement appeared in the Airmen's Special Report No. 8 from the Idflieg, dated 23 October, 1917:

'The best enemy single-seater is the S.E. 5; the Sopwith Triplane appears not to have been a success. At the Front many Triplanes have been seen to disintegrate when under heavy stress.'

The superiority of which Richthofen spoke appears to have been due to a lightweight, *i.e.* under-dimensioned structure, rather than to any inherent superiority in the triplane layout.

An Idflieg report dated 29 August, 1917, includes the following statement:

'In Siemens' opinion a good biplane can provide a better performance in every respect than a triplane.'

Nevertheless Siemens experimented with the triplane design along with eleven other companies, namely AEG, Albatros, Aviatik, DFW, Euler, Fokker, Friedrichshafen, LFG Roland, Pfalz, Schütte Lanz, and Siemens Schuckert.

Further Fighter Development

The aviation industry attempted to meet the Flying Corps' demand for triplanes, but this route offered no real prospect of increased performance; further work along the earlier line continued in parallel with the triplane efforts. On 9 July, 1917, it was stated that only the Albatros D III and D V could be considered as fit for operational use at the Front.

'Both are fitted with 160 hp Daimler engines and two fixed machine-guns. The D III is of more robust construction than the D V. The D V can be considered simply as a lighter version of the D III. The two designs are equal in terms of performance. Only the DIII is still being built.'

The wing of the D V was again set 10 cm lower in comparison with the D III, in an effort to improve the pilot's view further.

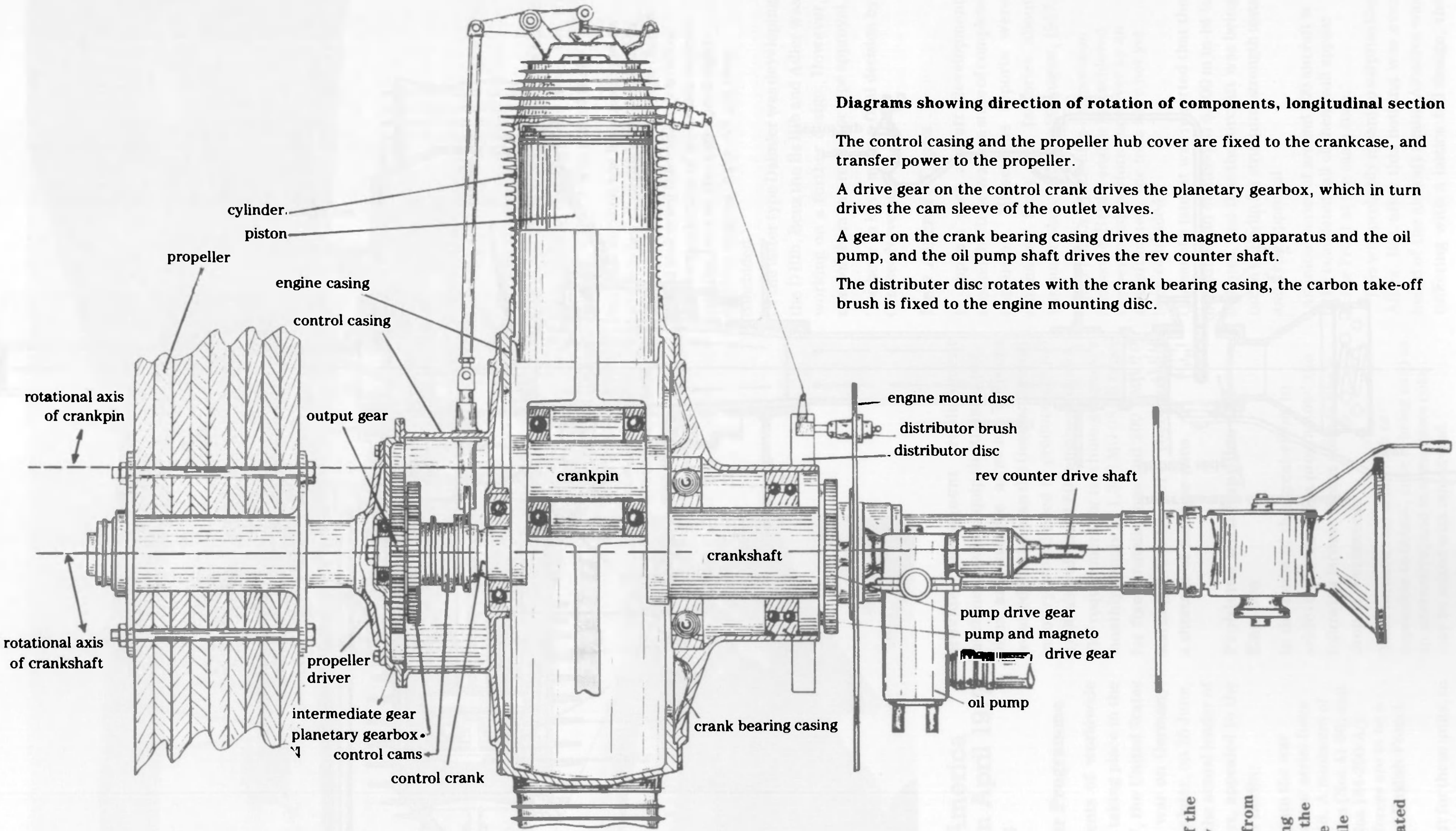
All the other available aircraft were simply rejected. The same report of 9 July continues:

'Overall assessment:
The Idflieg's primary task, entrusted to it by the Commander General of Aerial Forces, was to procure a new fighter aircraft. Quite apart from the many separate setbacks, the Albatros D III and D V aircraft no longer meet the requirements of the Front for a superior fighter aircraft. As the aircraft factory appears to have reached the limits in performance of the D-type, based on the 160 hp Mercedes engine, it is essential that the motor industry succeed in producing new power plants for the D aircraft. They must be more powerful, and be produced in large numbers.'

In spite of the pessimism expressed about existing fighters, 100 Albatros D IIIs and 200 Albatros D Vs were ordered in the following month, August 1917, with the explanation:

'Various reinforcements have been carried out on the Albatros D V. In consequence, a repeat order has been made.'

Evidently there was nothing better.



Diagrams showing direction of rotation of components, longitudinal section

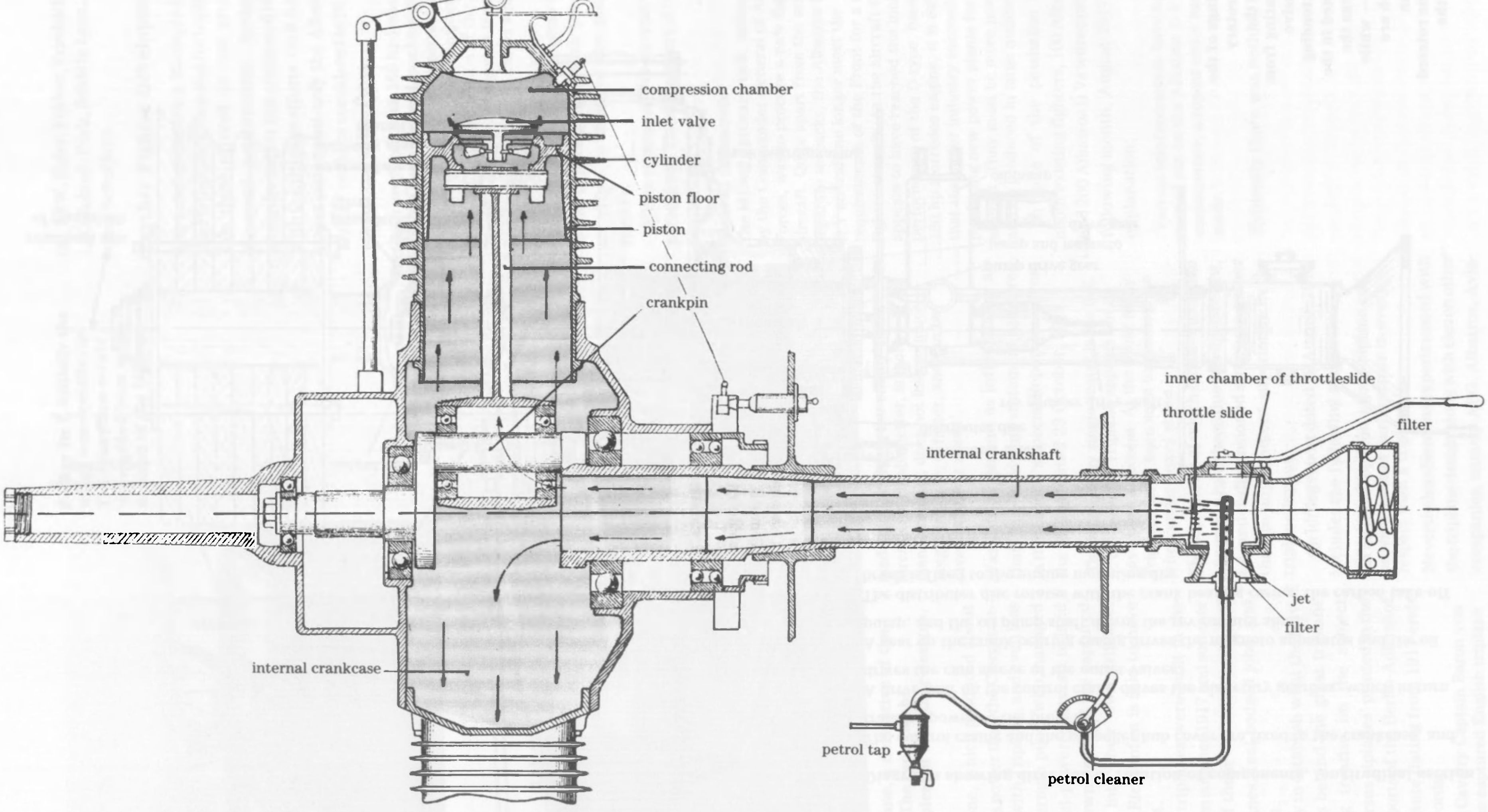
The control casing and the propeller hub cover are fixed to the crankcase, and transfer power to the propeller.

A drive gear on the control crank drives the planetary gearbox, which in turn drives the cam sleeve of the outlet valves.

A gear on the crank bearing casing drives the magneto apparatus and the oil pump, and the oil pump shaft drives the rev counter shaft.

The distributer disc rotates with the crank bearing casing, the carbon take-off brush is fixed to the engine mounting disc.

Original drawings of the Oberursel U I rotary engine used in the **Fokker Dr I, dating from 1917. The massive crankshaft, extending far aft, was fixed in the aircraft — it was the engine mount — while the parts which are stationary in an orthodox engine rotated together with the propeller.**


compression chamber
inlet valve
cylinder
piston floor
piston
connecting rod
crankpin
internal crankshaft
inner chamber of throttleslide
throttle slide
filter
jet
filter
internal crankcase
petrol tap
petrol cleaner

Albatros D V.

Albatros D V. Upper wing at pilot's eye level, rear view mirror, telescopic gun sight.

The Entry of America into the War in April 1917 and its Effects

Intensified Fighter Programme

In the meantime events of worldwide importance had been taking place in the war. On 6 April, 1917, the United States of America declared war on Germany. Two and a half months later, on 25 June, General Ludendorff, the actual leader of the German war effort, appealed to the Royal War Ministry in Berlin:

'The entry of America into the war obliges us to strengthen our aerial force significantly by 1.3.1918. A minimum of 40 new fighter squadrons (Nos.41-80) and 17 aircrew divisions (Nos.184-200/A/) must be set up, if our forces are to be a match for the combined English-French-American aerial fleet.'

To provide new aircraft for these units, to provide subsequent replacement machines, and to equip the training institutes and reserve airmen's divisions required for this plan the German aircraft industry would need to produce around 2,000 aircraft and 2,500 engines a month. The requirement for machine-guns was a monthly supply of 1,300 MG 08/15 types for fixed installations and 200 LMG 14, starting in October 1917. There was still a shortage of machine-guns.

Problems with Supplies and Engines

In the midst of this great effort to achieve the 'America programme' the following laconic report sounds like a drop of wormwood:

'blast furnace coal is difficult or impossible to obtain, coke is being used as an alternative, and in some cases coke may be mixed with mined coal.'

But there was a more serious obstacle to undertaking the plan on time. On 10 August, 1917, it was stated that:

'no final decision has been made yet on which types of engine are to be built in the future; the negotiations with Daimler aimed at forcing the company to allow licence production of Mercedes engines, and the tests on the high-speed eight-cylinder engines, have not yet been concluded.'

Of the latter type Daimler was developing the D IIIb, Benz the Bz IIIb and Adler was working on a further design. However, none of them was ready for type approval.

'We hope to have made a final decision by October/November.'

New Aircraft Types

It appears that aircraft development around this time was in a state of complete confusion. Miraculous reports were emanating from the factories about various triplanes. *E.g.* on 29 August, 1917:

'The Pfalz Dr I with high-compression Siemens & Halske engine has achieved the best climb performance ever by an aircraft on test; the tests have not yet been concluded.'

One month later it was reported that the machine had climbed to 6,000 m in 14 ½ minutes, and that the aircraft was being taken to Berlin for structural strength tests and type approval.

'An initial series of around 100 aircraft is to be completed; all of them will appear at the Front at the same time.'

This was probably meant to surprise the Allies. But after this nothing was ever heard of the aircraft again. Albatros was tinkering with a lattice tail design, the

Siemens lattice-tail triplane. Two Siemens rotary engines in tandem, with cockpit between them.

Albatros D VI, with a rear-mounted Daimler D III producing 160 hp, *i.e.* a return to the pre-1914 formula. Siemens made the same backward step. This was a twin-engined triplane fitted with 120 hp Sh I rotary motors, one in front of the pilot and one behind him. It was perhaps inevitable that the aircraft crashed on its first take-off. The Albatros machine also came to nothing, as did many other designs which appeared at this time. The great majority of designs stuck to the standard biplane formula with ailerons on the upper wing only, which meant that the roll response was unsatisfactory. The only advance was that more and more designs adopted balanced ailerons for reduced control forces, which made it easier for the pilot to obtain greater control surface movements. The fact that nothing successful came out of all these new designs is due simply to the lack of time between July 1917 — the time at which the requirement for the new fighter aircraft with a new engine (as yet not fully developed) was laid down — and March 1918, when the machine was to be introduced in large numbers. The Idflieg had to decide on the new machine in January 1918. It was clear to all that standardisation was necessary, and that there was no time for the usual pre-production series of aircraft chosen on the basis of company information. Thus the Idflieg arranged a comparative flying demonstration at Berlin-Adlershof.

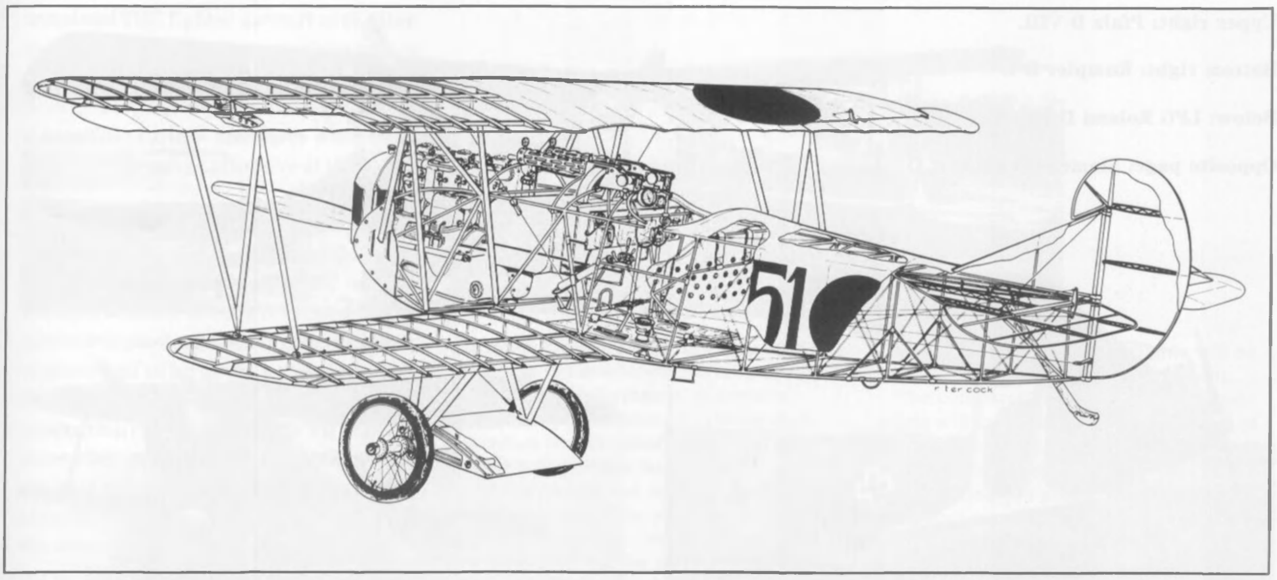
The Fighter Aircraft Competition of February 1918

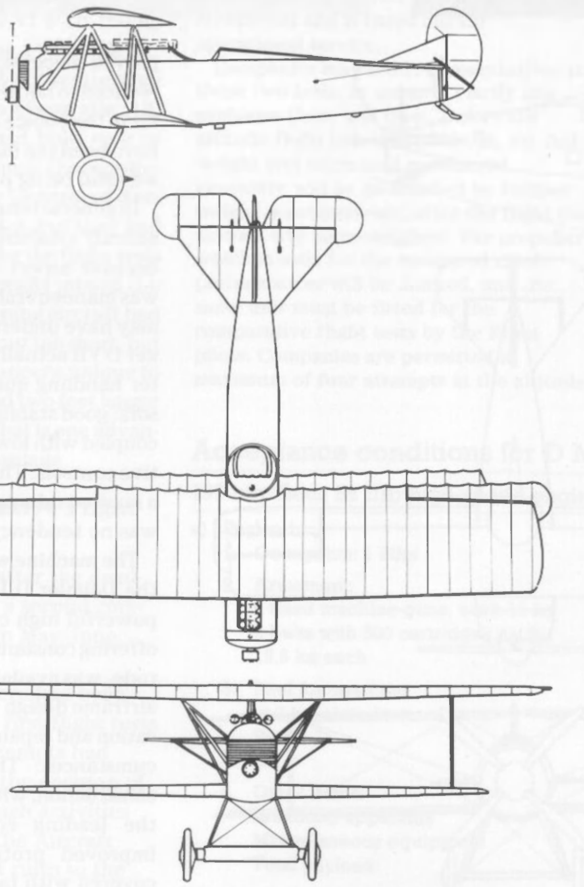
At the end of January and the beginning of February, twenty-three aircraft were presented for the competition, all of them biplanes apart from one monoplane and Two Fokker Dr I triplanes. One of the triplanes had a Siemens rotary engine, the other a Goebel, both of them more powerful than the standard version. Of the twenty biplanes the four which Fokker had brought were unbraced, the rest were single-bay and braced. There was virtually no trace of a new fighter aircraft with the new engine, both of which had been demanded by the Commander General in July 1917. The new airframes were equipped with proven old engines, as they had been designed before the new units were available; the new power plants were built into older designs. These new engines were of considerably older origin, and they were really only further developments of existing types. In fact, an engine takes longer to develop than an airframe.

If an engine is to be small and light in weight, its basic components are constantly run close to the limits of material fatigue, and at temperatures just below the theoretical maximum, whereas the air-

Fokker D VII.

Fokker D VII.





Fokker D VII

Wingspan	8.9 m
Length	7.0 m
Wing area	20.5 sq m
All-up weight	955 (900) kg
BMW IIIa	185 hp at 3,200 m
(Daimler D IIIa)	160 hp

craft is stressed for loads which it may only experience in exceptional circumstances.

The tests only measured and compared the machines' climb performance; there was evidently no time for speed measurements. The results of the competition were listed in order of climb times achieved, in two separate groups: air-cooled rotary engines and water-cooled stationary engines. As might be expected, the climb times of the aircraft with rotary engines was better than those with stationary engines. In the latter group the new high-compression 185 hp BMW IIIa, installed in an Albatros D Va, achieved the best climb times. Although neither the new Fokker V 11, nor the Fokker V 18 — a further improved version — produced the best climb performance among the aircraft equipped with the 160 hp Daimler D III engine, the Fokker V 11 was selected among the contestants in the competition. After certain modifications had been made to improve stability around the vertical axis the aircraft became the Fokker D VII, of which 400 were ordered immediately. As the Fokker factories were nowhere near capable of supplying such numbers in a short time, Albatros, the East German Albatros works and AEG were required to manufacture the Fokker D VII under licence.

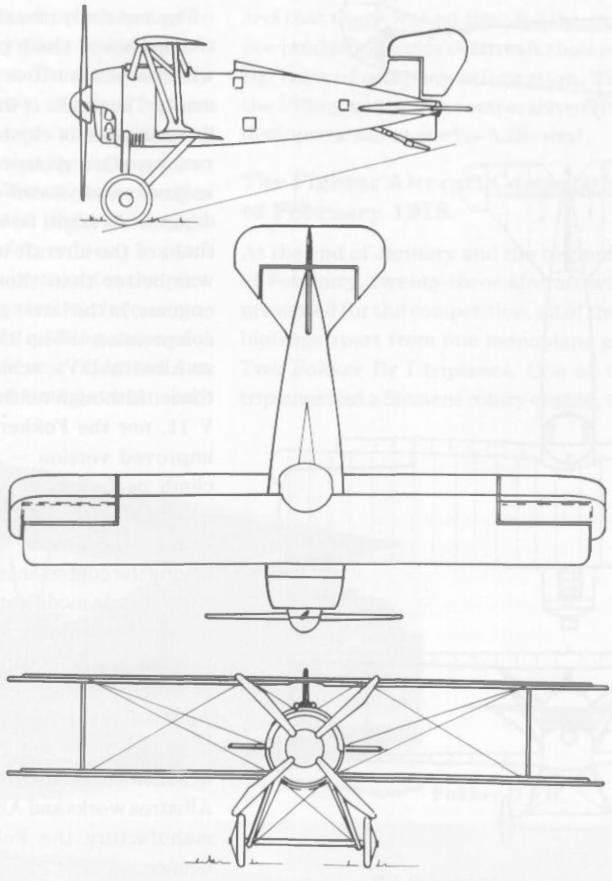
The Winner — the Fokker D VII. The Fokker V 11's superiority in performance over the proven Albatros D Va, both fitted with the Daimler D III engine, was largely due to a substantial weight advantage amounting to 60 kg. Later, when the D VII, as it was now called, had been fitted with all the strengthening which

Upper right: Pfalz D VIII.

Bottom right: Rumpler D I.

Below: LFG Roland D VI.

Opposite page: Siemens-Schuckert D III.



Siemens-Schuckert D III

Wingspan	8.4 m
Length	5.7 m
Wing area	19.0 sq m
All-up weight	725 kg
Sh IIIa	160 hp

proved necessary, this advantage was reduced to nothing. In fact the crucial factor in the choice of Fokker D VII may well have been the machine's handling, which was still being praised many years later.

In general terms pilots did not rate their aircraft's stability as very significant. The decisive aspect of a high-quality fighter was manoeuvrability, however the pilots may have understood the term. The Fokker D VII actually turned out to offer better handling qualities than its predecessors: good stability around all three axes, coupled with low control forces and effective controls. The machine also displayed a marked reluctance to tip-stall, *i.e.* there was no tendency to fall into a spin.

The machine was initially supplied with the Daimler D III engine until the more powerful high compression BMW IIIa ü, offering constant power up to 3,000 m altitude, was available in large numbers. The airframe design was well suited for fabrication and repair under the prevailing circumstances. The wing was of wood construction, with two spars, skinned over the leading edge with plywood for improved profile fidelity, the whole covered with fabric. The fuselage was a welded steel-tube framework in the standard manner which Fokker had employed since the first E I fighter. The structure was covered with fabric apart from the front section, which was skinned with sheet aluminium. All the tailed surfaces and the ailerons were made as fabric-covered steel-tube structures. By this time the Idflieg and all the participating pilots had selected the aircraft unanimously, and it

remained THE fighter aircraft of the German air forces until the end of the war. It was now the beginning of 1918. It would be necessary to work day and night if even a handful of these machines were to be ready for the spring offensive at the Front.

The Other Competitors. The principle of the standard fighter was inevitably watered down to some extent. It was not thought sensible to bet everything on the one power plant, and in any case the rotary engines had to be given a chance to realise their potential. In fact, quite large production runs of the Pfalz D VII or D VIII were planned, although production never got past the test series stage. In addition, according to the documents pertaining to the comparative flight tests, further series of 50 units of the following designs were also to be built: Rumpler D I with 160 hp D IIIa, LFG Roland D VI with 160 hp D IIIa and SSW D III with 160 hp Sh III.

The design offices of the other German aircraft companies had not been idle. All, or almost all, of them had built new or improved prototypes to meet the requirement of the Commander General of Aerial Forces for a new fighter, but they had been completed too late for the flight tests in January. Fokker had really missed the deadline too, and his winning aircraft had — dear oh dear — turned out too short, but with the energy and unconcern unique to the man he rebuilt it a good two feet longer over Saturday/Sunday. That is one advantage of the steel-tube fuselage.

The Second Comparative Flight Test, May 1918

The aircraft completed after the deadline were assembled for a second competitive demonstration in May/June, again at Aldershof.

The story goes that there had been irregularities during the first flight tests in January/February; attempts had been made to influence the decision of Front pilots. This time such activities were to be eliminated. The Aircraft Department sent a set of rules to the participating firms, which are reproduced below in a slightly abbreviated form:

'Aircraft Department
Charlotottenburg 5 May 1918

Regulations concerning the comparative flight testing of D aircraft, June 1918

In order to complete every part of the preparatory work before the comparative testing is carried out by the Front pilots, work will begin on the D aircraft already

at Aldershof on 22.5.18, starting with weighing the machines and measuring their flying performance. If possible, companies are requested to bring their machines to Aldershof before this date, and in any case not later than 1 June.

After arriving and rigging the D aircraft the appropriate firm will be notified that on a particular day the empty weight of each machine will be measured. Two officers will also check that the aircraft is fitted with the correct technical equipment and is fitted out for operational service.

Companies may send representatives to these two tests, in order to clarify any problems there and then. Before the altitude flight test is carried out, the full weight and extra load considered necessary will be established by further weight measurements; after the flight the aircraft will be re-weighed. The propeller which is used for the measured climb performances will be marked, and the same unit must be fitted for the comparative flight tests by the Front pilots. Companies are permitted a maximum of four attempts at the altitude flight. Two of the altitude flights will be used as basis for the final assessment.

The comparative flight tests by Front pilots will take place after completion of the altitude tests. Companies will be informed by telegraph of the date of the tests. During the actual flight testing by the Front pilots the firms' representatives will not have access to the take-off area. Speed, manoeuvrability and climb performance will be established by formation flying and simulated aerial combat. The Front pilots will record their assessment of the machines in question in writing, immediately after landing. When the Front pilots are flying, the take-off area will be cordoned off by military personnel.

As soon as the aircraft have been evaluated by the Front pilots, they may be demonstrated by the companies' representatives, who may discuss the machines with the Front pilots.

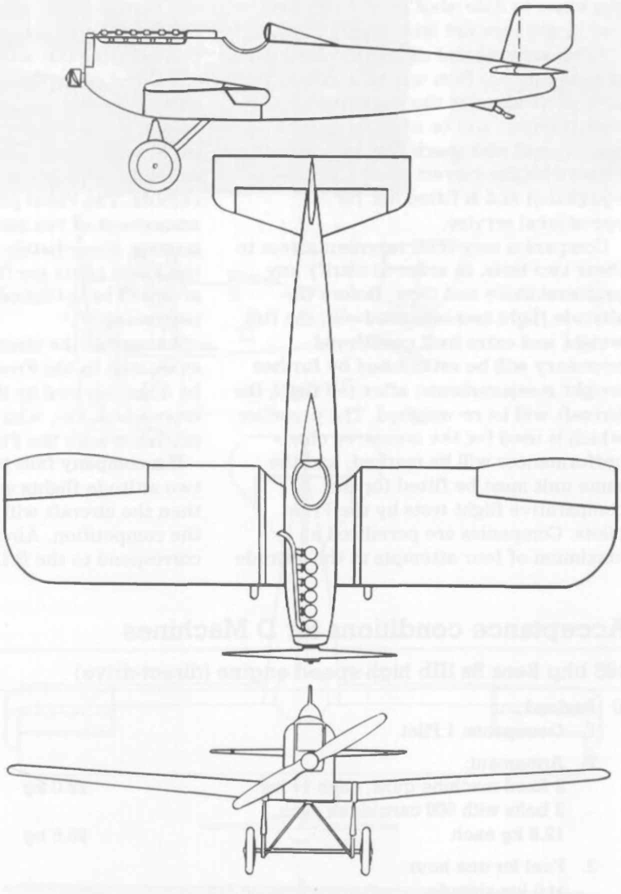
If a company fails to start the motor for two altitude flights within a stated time, then the aircraft will be eliminated from the competition. Aircraft which do not correspond to the B.L.V. building and

Acceptance conditions for D Machines

195 bhp Benz Bz IIIb high-speed engine (direct-drive)

a) Payload		
1. Occupants: 1 Pilot		80.0 kg
2. Armament:		
2 fixed machine-guns, each 11 kg	22.0 kg	
2 belts with 500 cartridges each, 12.8 kg each	25.6 kg	47.6 kg
3. Fuel for one hour at 0 km altitude:		
Petrol	45.0 kg	
Oil	5.0 kg	50.0 kg
4. Other items:		
Breathing apparatus	5.0 kg	
Miscellaneous equipment	7.4 kg	12.4 kg
Total payload:		190.0 kg
b) Fuel tank capacity for 1½ hours' operation:		
Main petrol tank	75 litres	
Auxiliary petrol tank	20 litres	
Oil tank	12 litres (incl 3 litres air)	
c) Climb performance:		
Climb class 60/25		
d) Level flight speed:		
180-190 km/h at 4,000 m altitude.		
e) Take-off and landing distance:		
If possible below 100 m.		

Junkers J9 (D I).



Junkers J9 (D I)

Wingspan	9.5 m
Length	7.8 m
Wing area	17 sq m
All-up weight	900 kg
BMW IIIa	185 hp at 3,200 m

supply regulations may not be flown by the Front pilots, before their safety standards are proven by gaining type approval. When the tests are completed the aircraft will be returned to the firms by Flz. A.

signed: Wagenfur
Witness
signed: (signature)'

Together with a copy of these conditions, the Aircraft Department sent an explanation of the required loading for the test flights and the requirements for fuel tank sizes and minimum performance. As an example, the values for a 185 hp D aircraft:

The participants. This time 37 aircraft were presented for the competition, of 31 different types — five of which differed only in their power plant. Fokker alone brought ten machines, although three of them were absolutely identical apart from their engines.

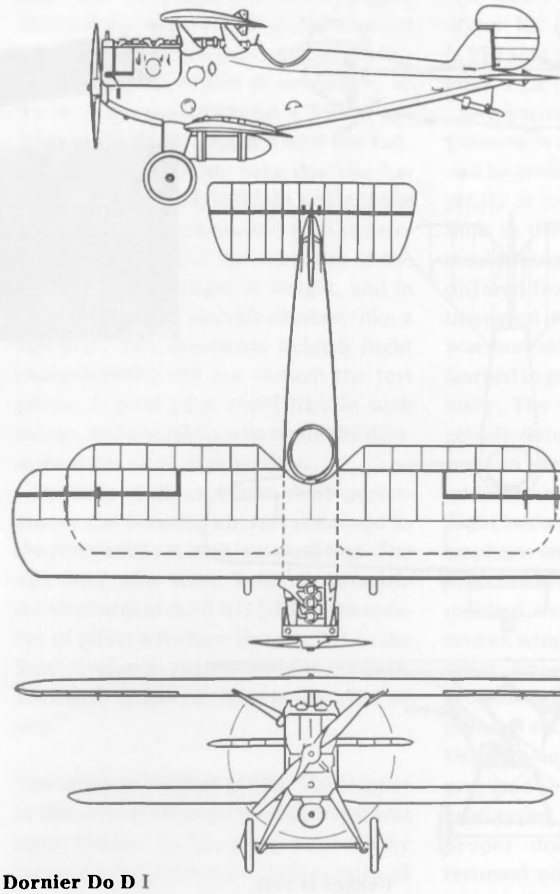
These three were cantilever high-wing designs with rotary engines made by three different manufacturers. Fokker had also brought with him a low-winger, a shoulder-winger and a fourth high-wing type, the last with stationary engine, and all of them of cantilever design. In addition there were two standard D VIIs fitted with Daimler D III motors, such as were now in service at the Front, plus one D VII with the high compression Daimler D IIIa ü and one with the high compression Benz Bz IIIb ü which were designated V 21 and V 24 respectively.

Of the remaining aircraft eighteen were braced biplanes, thirteen of them single-bay and five two-bay types. And finally there was the precursor of a new period, the Junkers J 9 (D I): a cantilever all-metal low-wing monoplane.

Fokker had also brought a low-winger, the V 25, of wood and steel-tube construction. The surprising feature of this machine was the total lack of wing dihedral; after all, Fokker had been granted a patent (No.265 515) for wing dihedral in 1912 to increase stability, although the reasoning behind the patent was somewhat curious. In its state as presented for the competition the machine must have exhibited negative yaw/roll moments, and in consequence it is unlikely to have impressed the pilots with its handling in the air.

To a present-day aerodynamicist the appearance of the Junkers J 9 inspires some degree of confidence. A slightly enlarged fin, narrower ailerons with

Zeppelin (Dornier) D I.



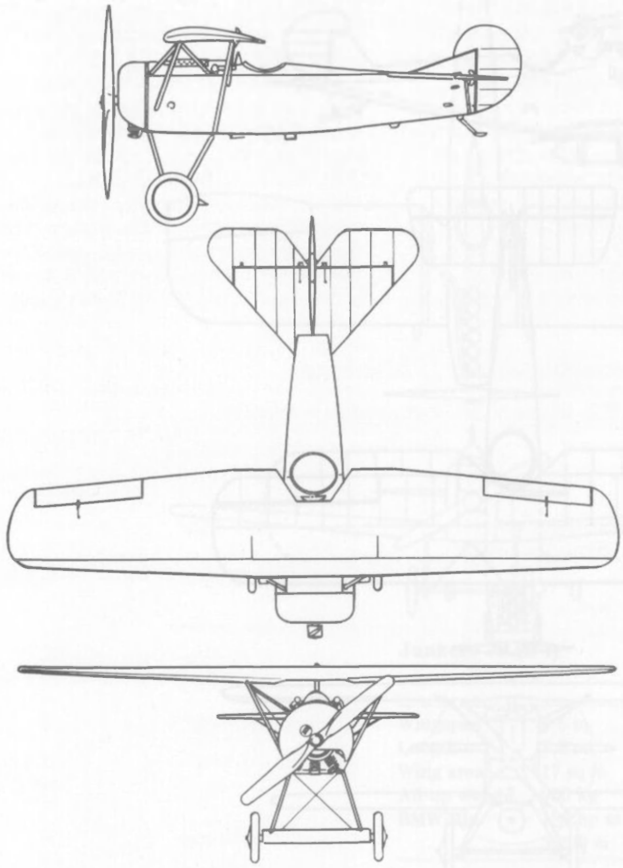
aerodynamic balances, and no-one could have any serious objections. Especially if we consider the later version fitted with the BMW IIIa with — far ahead of its time — a belly radiator installation, it would be easy to imagine that the aircraft dated from the thirties. The machine which appeared for the second comparative flight tests, powered by the Daimler D III engine, had its radiator fitted at the front; an arrangement which was gradually beginning to supersede the widely used wing-mounted installation. The latter arrangement gave the aircraft a more racy appearance, because the radiator was concealed, but it produced higher drag than the frontal radiator, as wind-tunnel tests in the Göttingen aerodynamic testing institute (at that time still the model testing institute) has shown. The all-metal construction of the Junkers monoplane, which was a complete innovation, represented an insuperable obstacle to mass production at the time. Nevertheless, and in spite of certain deficiencies in flying characteristics, Junkers was awarded a contract to enable work on the concept to continue.

At the very last minute, too late for the actual competition, a cantilever (almost) true all-metal biplane appeared, designated the Zeppelin D I, and built under Dornier's direction. The structure of this aircraft represented a significant advance. It also showed progressive thinking in its aerodynamic design. The wings, with a section 13 ½ per cent thick, were based on three spars, the front spar at 25 per cent

Dornier Do D I

Wingspan	7.8 m
Length	6.4 m
Wing area	18.7 sq m
All-up weight	885 kg
BMW IIia	185 hp at3,200 m

Fokker D VIII.



Fokker D VIII

Wingspan	8.35 m
Length	5.85 m
Wing area	10.7 sq m
All-up weight	605 kg
Oberursel UR II	110 hp

chord, the rear spar at 55 per cent chord. The smooth duralumin skin extended back as far as the rear spar, forming a rigid box-section structure which absorbed all the bending and torsional loads. The fuselage was also built as an all-metal shell skinned in smooth sheet, from which the cantilever fin, upper wing struts and undercarriage legs projected. The petrol tank was external, slung under the fuselage, and could be dropped in an emergency.

The aircraft was built in the greatest possible haste. Project lodged at the beginning of February 1918. Provisional approval granted by the Idflieg on 17 February. Approval granted by the War Ministry on 28 February. Contract awarded by the Idflieg on 11 March. First flight on 4 June at Friedrichshafen. Immediately afterward, despatch to Aldershof by rail. While the machine was being fitted out there, it was discovered back at the factory that the wing attachment fitted was too weak. The firm ordered the aircraft grounded until new fittings arrived. The new parts were

put on the train, but in the meantime pilots at Aldershof were already flying the machine; there was simply no time to lose. Inevitably the component fractured, the upper wing detached itself, and the pilot was killed. 'Haste makes waste', as the Americans would say. Were the pilots given a clear warning? Or did they carry on regardless, unconcerned and unheeding? In this accident, as in thousands of similar ones, we will never know the answer.

In spite of the mishap, and in spite of certain deficiencies in the machine's handling, work continued on it, because it looked right and promised eventual success. The machine was judged to lack true fighter qualities: 'Aileron forces too high'. As already noted, it is suspected that the pilots of the time (and some later pilots) really meant roll response when they spoke of manoeuvrability, and that low aileron control forces were a characteristic of good response. If an aircraft was inadequate in this department, it failed the test. Neither the industry nor the customer knew what could and should be done to remedy the fault.

Aerodynamic knowledge was still very limited, and at this time hardly any systematic experiments were being made with a view to establishing a base of such knowledge. In the quest for improved performance, the general motto was still 'practical testing beats research'. Analysis, the principal tool in aircraft development in the late thirties and thereafter, was virtually unknown. The Siemens-Schuckert D III aircraft with the Siemens & Halske Sh III engine, which proved superior to all others in the first comparative climb tests, was thought to be slightly less satisfactory in respect of speed. Precise data were not available, for speed measurements, especially at higher altitudes, were still very dubious. We will return to this shortly. We know that Siemens-Schuckert was making efforts to improve performance after the first comparative flight tests:

'The company has begun tests aimed at increasing the D III's speed. It has been granted for this an increase in the time to climb to 6,000 m to 25 minutes.'

Siemens reduced the size of the lower wing of the D III, so that the total wing area was now 15.1 sq m instead of the original 18.8 sq m, but the resultant reduction in wetted area was only about three per cent, which would have provided a one per cent speed increase, *i.e.* 1½ to 2 km/h. This is easy to calculate if you have a little knowledge of aerodynamics. The aerodynamicist of today could be excused for shouting to those of 1918: 'Can't you see the angle between your circular fuselage and the bottom wing? Look how Pfalz solved the problem in the S III back in 1917'. But the Siemens designer was undoubtedly too proud of his circular barrel, which had also turned out far too short. The low weight of the rotary engine dictated an excessively short tail moment — the distance from the centre of gravity to the tailplane centre of pressure — of 3.4 m, compared with the 4.7 m of the Pfalz aircraft and almost 5 m of the Fokker D VII. No wonder then that the Siemens aircraft easily fell into a spin if the pilot was over-enthusiastic with the elevator in a turn. But the small size of the machine made it light in weight, and in consequence the aircraft climbed 'like a monkey'. The somewhat ticklish flight characteristics did not disturb the test pilots. A good pilot could handle such things, and the pilots who made the decisions were all of high quality.

Because of its excellent climb performance the Siemens aircraft remained in the programme at least in a small way. The aim may also have been to promote development of the S & H D III. In the opinion of pilots who flew the aircraft in the Baltic region in 1919, it had the best performance of any machine in the 1914-18 war.

Comparison of Fokker Dr I and D VIII

Power plant: 9-cylinder Oberursel UR II 110 hp

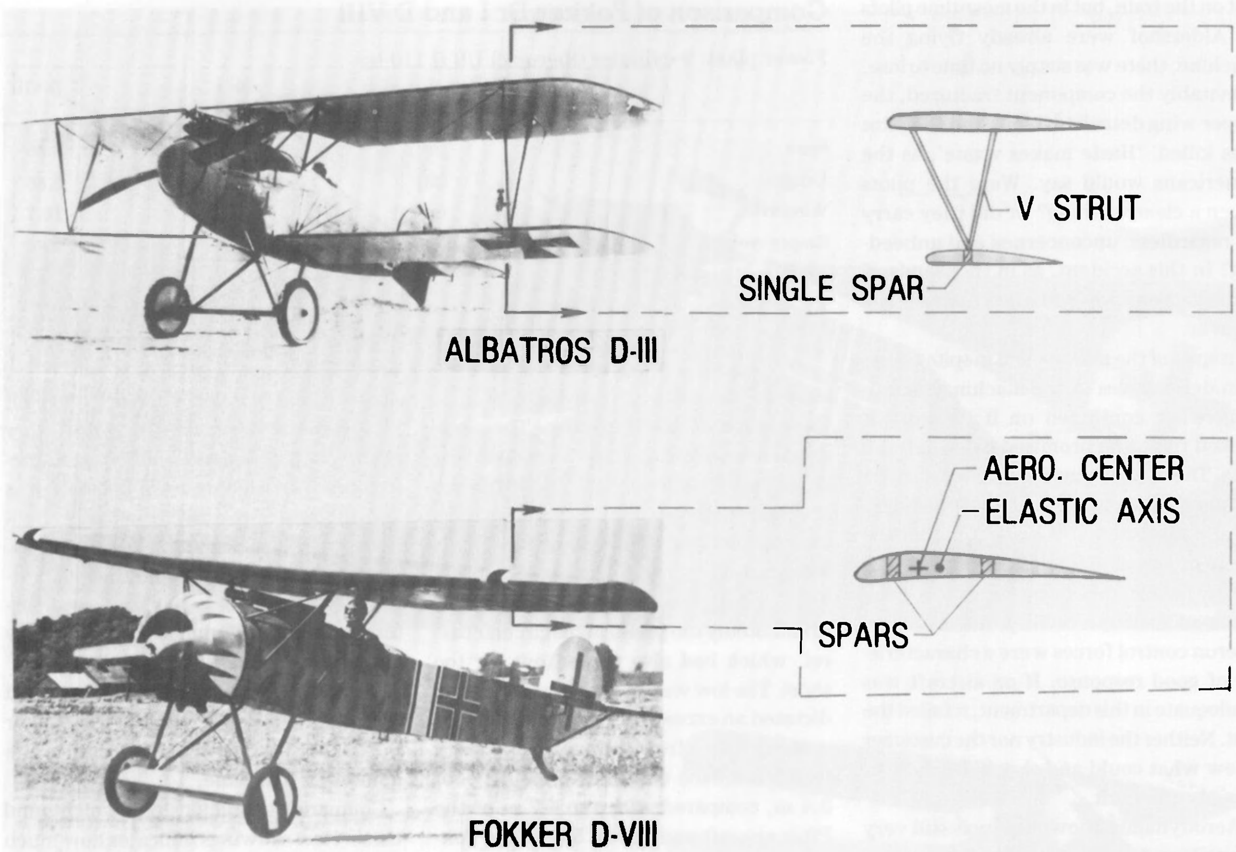
		DR I	D VIII
Span	(m)	7.2	8.35
Length	(m)	5.75	5.85
Wing area	(sq m)	18.7	10.7
Empty weight	(kg)	405	405
Additional payload	(kg)	180	200
All-up weight	(kg)	585	605

The winner: Fokker D VIII. The winner of this second comparative flight test was again Fokker. In the group powered by water-cooled stationary engines none of the competitors showed a sufficient advantage over the Fokker D VII to knock it from its perch, bearing in mind the aircraft's good flying characteristics, and the large-scale production which was already under way. Among the ten Fokker designs taking part in the second test series one showed great promise. This was the small, light Fokker V 28 with its 110 hp U II rotary engine. Its performance and flying characteristics were so encouraging that it was immediately approved for mass production under the designation Fokker D VIII. The climb time achieved in the competition — 21.6 minutes to 5,000 m — was better than aircraft equipped with stationary engines producing 160-180 hp.

In fact it was this aircraft, introduced under its military designation Fokker D VIII that was the true successor to the Fokker Dr I triplane.

Comparing the dimensions, weights and three-view drawings indicates how much can be gained by clear thinking and simplicity of construction. The fuselage was built in the standard Fokker way using steel tubing and fabric, and in fact only differed from the triplane fuselage in its increased depth at the tail end, *i.e.* there was more side area at the rear. Fokker had learned to pay attention to directional stability. The wing was two-sparred, completely skinned with plywood. The result was an extraordinarily stiff structure which was intended to be equal to any flight loads when built carefully. Note the emphasis on the word 'intended', because just a few weeks after the first aircraft had reached the Front, three of them had broken wings. The aircraft, on which such great hopes had been pinned, was grounded on 21 August. The design was revised with the help of the Aviation Department, and accurate drawings were prepared — Fokker apparently built the prototypes in the workshop without proper documents. Production was resumed on 24 September, and all the wings built until then were scrapped. Thus this highly promising design did not arrive at the Front until 14 days before the end of hostilities.

More than 60 years later the Fokker D VIII and the Albatros D III were examined by two American authors in an



Albatros D III and Fokker D VIII, wing torsion. (NASA report)

investigation of the flutter problem. (Garrick and Reed of NASA Langley Field) (see illustration above).

A description of the 37 aircraft taking part in this second comparative test series, and the new designs which continued to appear, would fill a whole book. The assessors must have had fearsome difficulties in separating the different types in terms of performance and flying characteristics. The climb performances could be measured with some degree of reliability, using three barographs for each flight, although the scatter among the three instruments was considerable. However, measuring airspeed, especially at great altitudes, was extraordinarily difficult, and there was absolutely nothing against which to judge flying characteristics and handling.

It must be said that measuring flying performance is a science in itself; it was decades before a reasonably reliable system was designed which allowed the values measured on one day in a given set of conditions to be converted to another day with different weather or a normal day.

This inadequacy was well known, but it was not known how to compensate for it, and above all how to make sense of the data supplied by the industrial companies who, ever striving for new business, were only too keen to broadcast fairy tales about their products; a practice which was still just as popular a quarter of a century later.

The Aircraft Department of the Idflieg had already set up a station at Rechlin an der Muritz, 100 km north of Berlin, whose purpose was to measure flying speeds accurately using theodolites. But the procedure was complex and time consuming; it was quite unsuitable for a competition with so many participants, the sole point of which was to establish the best fighter aircraft in the shortest possible time. Time was terribly short.

The Third Comparative Test Series in October 1918

The Idflieg sought to escape the dilemma by requiring the aircraft to fly in pairs side by side, in each case establishing which was faster. It gradually dawned on the authorities in the Idflieg, however, that it made little sense to compare aircraft fitted with different power plants, and that no real increase in performance could be obtained without more powerful engines. Of the available engines the 185 hp BMW IIIa was by far the best, in terms of power at altitude, operational reliability, fuel consumption and weight. For this reason a third comparative test series was arranged for October 1918, in which the aircraft with stationary engines were fitted only with BMW IIIa power plants.

Of the larger rotary engines (160 hp class) not one could get anywhere near the operational reliability of the BMW. Nevertheless, the weight advantage of the rotary design was undeniable, and hence development of aircraft with these motors was allowed to continue.

Of the fifteen aircraft entered in this final test series, seven were built according to the Fokker D VIII formula, two of them fitted with BMW IIIa units. Only two braced biplanes were among the competitors, along with four further biplanes, more or less emulating the Fokker D VIII. So much fuss had been made about the Pfalz braced two-bay biplanes in the previous test series that a considerable number of them had been ordered immediately, despite the fact that they represented a return to the style of 1915. But this time even Pfalz had adopted a configuration which was similar in structural terms to that of the Fokker D VII. Certainly the two-

Above: LFG Roland D XVI

Albatros DXI.

bay layout with its inherent rigidity had its merits, but there must have been serious faults, since the Pfalz D XII and D XIV disappeared more or less without a trace. It is likely that both types suffered from high drag due to the many struts and wires, and poor flying characteristics due to the excessively short tail length.

The Junkers Ju D I all-metal cantilever monoplane and the similarly all-metal Do D I cantilever biplane made by Zeppelin (Dornier), both equipped with new BMW engines, were also represented.

No reliable report of the results of this last test series has ever been discovered. A few days later came the collapse and with it the end of all work on combat aircraft in Germany — in fact, virtually all development on aircraft in general — for a long time.

The Fighter Aircraft Built between 1914 and 1918

One hundred and sixty seven fighter aircraft types, perhaps a few more, had been built in the four years from 1914 to 1918; 106 of them were biplanes, fifteen were tri- (and more -planes), the rest monoplanes. The following table includes the specification of the 40 aircraft of which more than 20 — most of them considerably more — were built. Speed information has not been included; the explanation for this is given in the following chapter.

Fighter aircraft, 1914-1918

Built in numbers greater than 20, in chronological order

Aircraft type	Engine type	Engine power	Aircraft weight kg (empty/ all up)	Wing-span m	Length m	Wing area sq m	Wing loading kg/sq m	Power loading kg/kW	Configuration
1914/15									
Fokker E I	Oberursel U 0	60/ 80	360/565	8.95	6.75	14.5	39	9.3	
Pflaz E I	Oberursel U 0	60/ 80	345/535	9.25	6.3	16	34	8.9	
Fokker E II	Oberursel U I	75/100	370/580	9.5	7.2	15.5	35	7.8	
Pfalz E II	Oberursel U I	75/100	410/620	10.2	6.45	16	39	8.2	braced monoplane
Fokker E III	Oberursel U I	75/100	400/610	9.5	7.2	15.5	39	8.1	
Fokker E IV	Oberursel U III	110/150	465/725	10.0	7.5	16.5	44	6.6	
Pfalz E IV	Oberursel U III	110/150	470/675	10.2	6.6	16	42	6.2	
1916									
Halberst D I	Argus AS II	75/100							
Fokker D I	Daimler D II	90/120	465/670	9.05	5.7	22	30	7.4	two-bay biplane
Fokker D II	Oberursel U I	75/100	385/580	8.75	6.4	18	32	7.7	two-bay biplane
Fokker D III	Oberursel U III	110/150	450/710	9.5	6.3	20	36	6.5	two-bay biplane
Halberst D II	Daimler D II	90/120	560/770	8.8	7.3	24	33	8.5	two-bay biplane
Albatros D I	Benz Bz III	110/150	650/900	8.5	7.4	23	39	8.2	single-bay biplane
LFG D I	Daimler D III	120/160	700/930			23			single-bay biplane
Fokker D V	Oberursel U I	75/100	365/570	8.75	6.05	18	32	7.6	single-bay biplane
LFG D II	Daimler D III	120/160	715/955	8.95	6.95	22	43	7.9	single-bay biplane
Albatros D II	Daimler D III	120/160	640/890	9.5	7.4	24.5	36	7.4	single-bay biplane
Halberst D III	Argus As II	90/120	560/770	8.8	7.3	24	32	8.5	two-bay biplane
Fokker D IV	Daimler D III	120/160	610/840	9.7	6.3	21	40	7.0	two-bay biplane
LFG D IIa	Argus As III	130/180	640/850	8.9	6.95	22	39	6.5	single-bay biplane
1917									
Albatros D III	Daimler D III	120/160	660/900	9.05	7.4	20.5	44	7.5	single-bay biplane
LFG D III	Argus As III	130/180	720/960	8.9	7.0	22	44	7.4	single-bay biplane
Albatros D V	Daimler D IIIa	120/160	680/920	9.05	7.4	21	44	7.6	single-bay biplane
Pfalz D III	Daimler D III	120/160	700/930	9.4	6.9	22	42	7.8	single-bay biplane
Albatros D Va	Daimler IIIa	130/180	720/960	9.05	7.4	21	46	8.0	single-bay biplane
Fokker Dr I	Oberursel U II	80/110	410/590	7.2	5.8	19	32	7.4	strutted cantilever triplane
Halberst D IV	Benz Bz III	110/150	525/740	8.8	7.3	24	31	6.7	single-bay biplane
1918									
Pfalz D IIIa	Daimler D IIIa	130/180	700/935	9.4	7.1	22	42	7.2	single-bay biplane
SSW D III	Sh III	120/160	535/725	8.4	5.7	19	38	6.1	single-bay biplane
Fokker D VII	Daimler D IIIa	120/160	700/900	8.9	7.0	20.5	44	7.5	cantilever biplane
	BMW IIIa	135/185	735/955	8.9	7.0	20.5	47	6.8	strutted cantilever biplane
Pfalz D VIII	Siemens Sh III	120/160	560/740	7.5	5.7	17	43	6.2	two-bay biplane
Rumpler D I	Daimler D IIIa	130/180	630/845	8.4	5.8	16	53	6.5	single-bay biplane
Fokker D VI	Oberursel U II	80/110	395/585	7.7	5.9	17.5	34	7.3	cantilever biplane
LFG D VIa	Daimler D IIIa	130/180	675/875	9.4	6.3	23	38	5.5	single-bay biplane
Fokker D VIII	Oberursel U II	80/110	405/605	8.3	5.9	11	55	7.5	cantilever monoplane
LFG D VIb	Benz Bz IIIa	145/200	645/900	9.4	6.3	22	41	6.2	two-bay biplane
Pfalz D XII	Daimler D IIIa	120/160	720/900	9.0	6.4	22	41	7.5	two-bay biplane
Pfalz D XIV	Benz Bz IV	145/200	835/1035	10.0	6.3	25	41	7.1	two-bay biplane
SSW D IV	Siemens Sh IIIa	120/160	540/735	8.4	5.7	15	46	6.1	single-bay biplane
Pfalz D XV	BMW IIIa	135/185	745/955	8.6	6.5	20	48	7.1	strutted cantilever biplane

The State of Aircraft Technology at the end of the First World War

In the space of four years the fighter had developed from a machine whose structural refinement was not much greater than that of the present-day hang-glider, to an all-metal cantilever machine, although wood, steel-tubing and fabric were still the primary building materials at the end of the war.

This conservatism was to a large extent determined by outside influences: basically pressure of time. It is not possible to retrain a team of cabinet makers as metal workers overnight, nor to convert a plywood factory into one for working sheet aluminium. New constructional methods can only be adopted step by step. It makes no sense to risk a new feature in an aircraft, *e.g.* a new design of undercarriage, unless the design engineers have the time and the resources.

The undercarriage was one of the first elements to undergo the standardisation process. It consisted of two V-struts, to which were attached the runner cords for springing the usually one-piece axle. It is possible to say without exaggeration that all fighter aircraft, German and Allied alike, had the same undercarriage. An article about this type of undercarriage, written early in 1918, states the following:

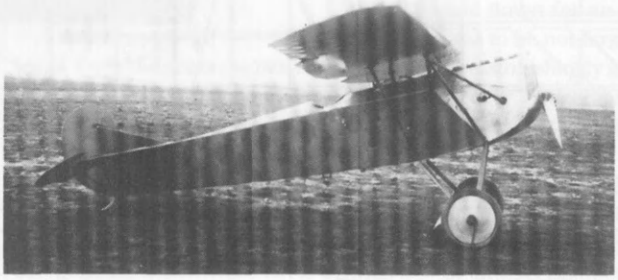
'It is by now well accepted that there is little room for improvement with this undercarriage design in terms of drag, simplicity and weight, and hence the only way in which a major advance can be expected is in retracting the undercarriage into the fuselage in flight. It is doubtful whether this is feasible for our light machine, since the weight of the retracting mechanism would probably outweigh other advantages.'

And this when the drag of the undercarriage represented more than 20 per cent of the total drag of a single-bay braced biplane!

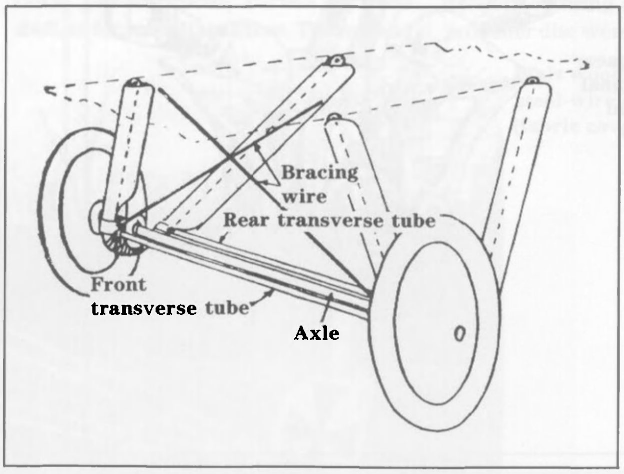
The construction of wooden wings was virtually everywhere. The ribs were threaded onto the spars, after which spacer struts — usually made of steel tubing — were fitted between the spars. The open areas were then braced with diagonal steel wires which were tightened by turnbuckles. The spar fittings, especially at the junctions where inboard struts, main wing struts and inboard and outboard bracing wires were attached, were often minor works of art fabricated in sheet steel.

At a very early stage Fokker replaced the

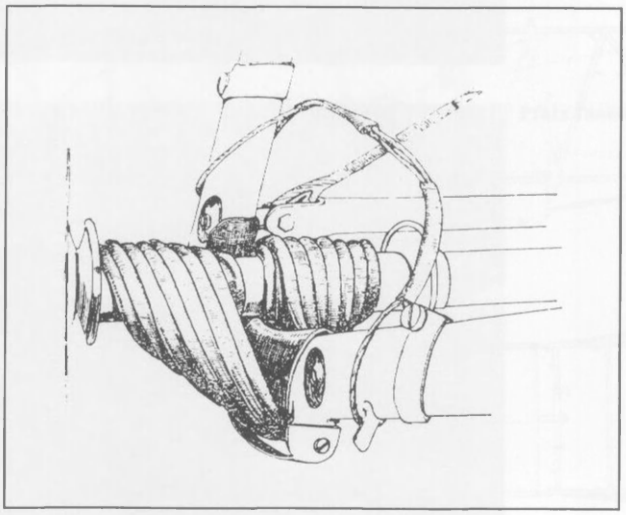
Pfalz D XV.



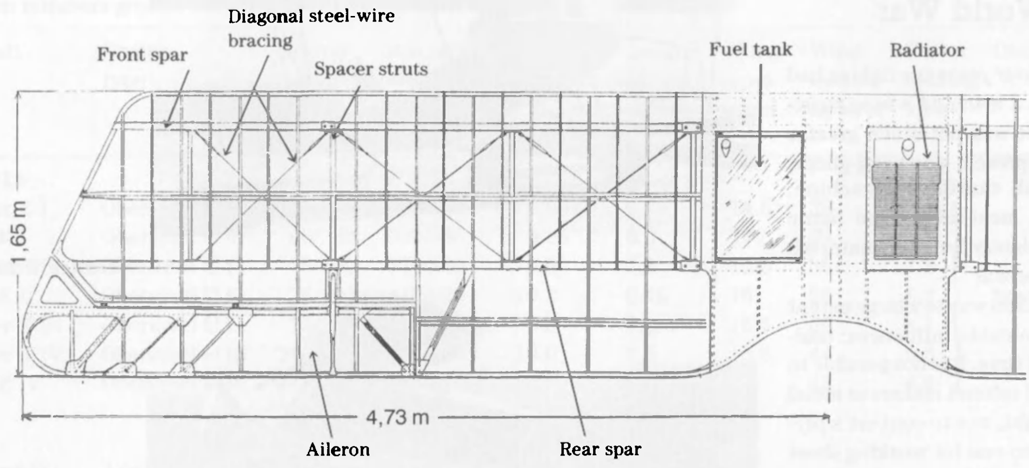
Fokker V 29.



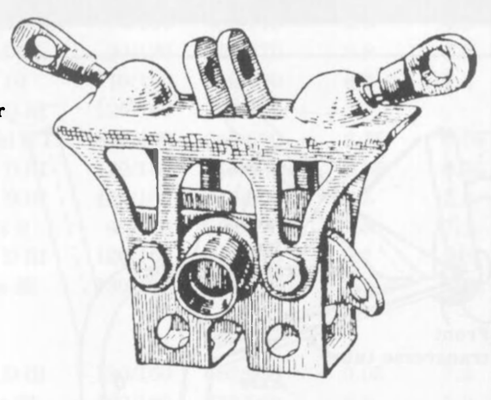
The standard undercarriage design — it was virtually universal.

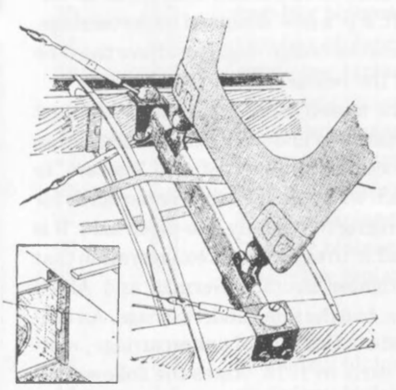


The almost standard method of wing construction.

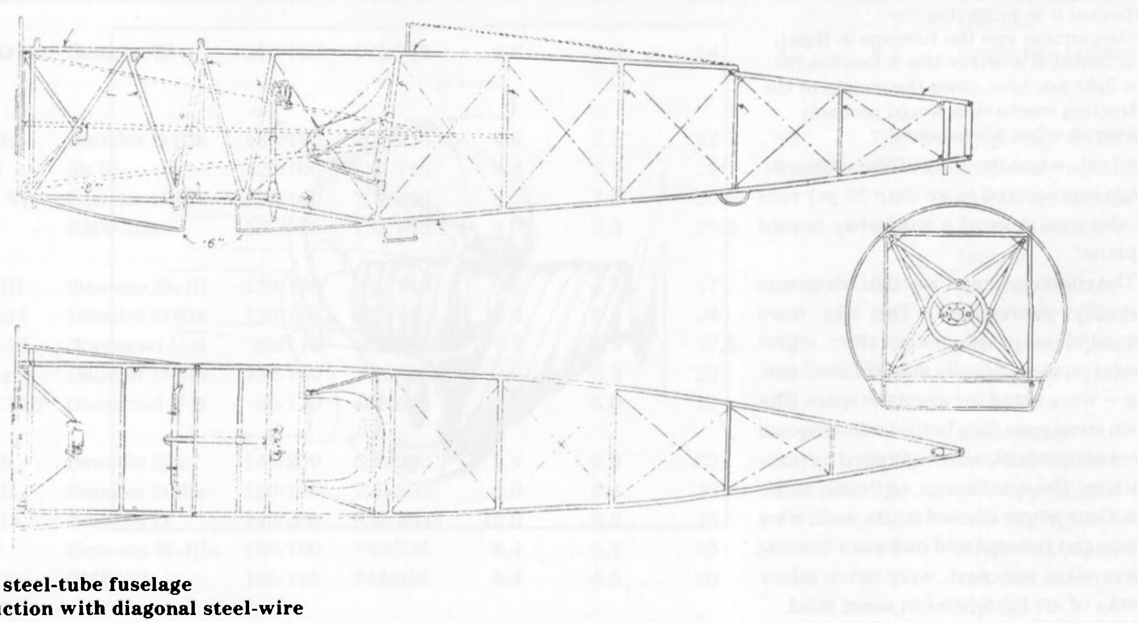


Wing spar fitting fabricated from sheet steel, providing attachment for interplane strut, spacer strut, interior diagonal bracing and external wing bracing wires.

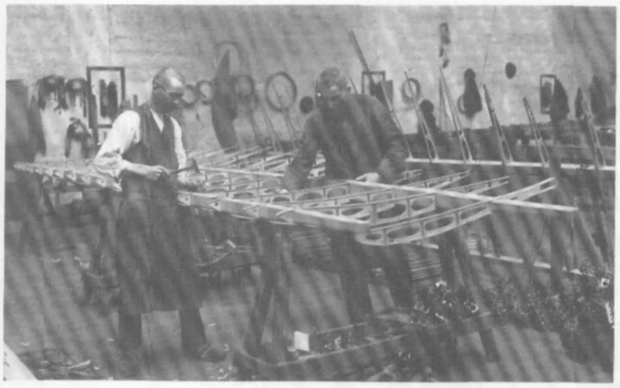




Attachment of interplane strut to lower wing.



Fokker steel-tube fuselage construction with diagonal steel-wire bracing.



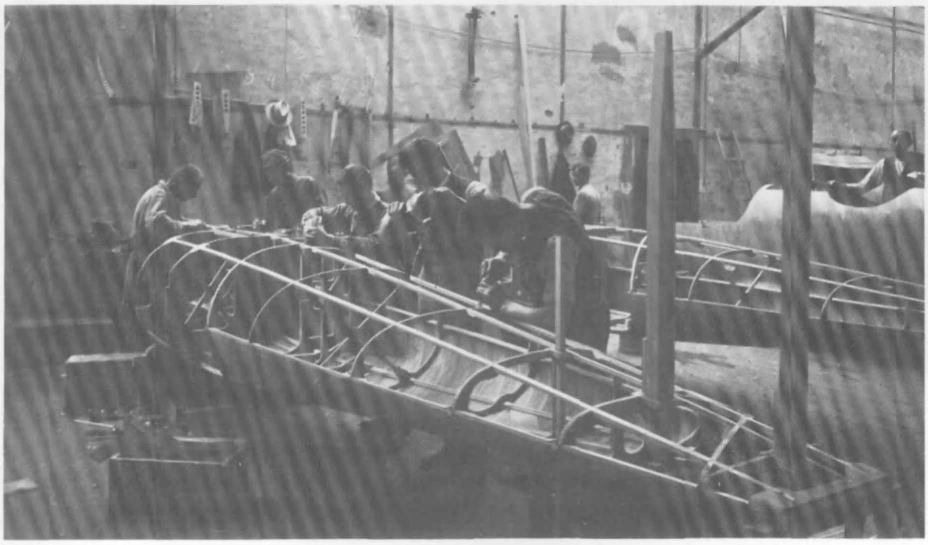
Wing assembly.

standard fabric-covered wooden strut fuselage framework by a steel-tube structure, which was welded at all the critical junctions. The areas between the struts were braced with diagonal wires in both versions. Albatros based its designs on a framework consisting of formers and stringers which was skinned all round with plywood to form a box fuselage which had great resistance to torsion and bending loads. Over the years the basic design was rounded off more and more, until eventually almost a pure monocoque construction had developed. The technique was taken to a high level of sophistication at LFG-Roland and Pfalz, whose fuselages consisted of a small number of relatively weak components which were covered with a thick, pre-fabricated, curved plywood shell, to form a stiff structure. This method of construction offered many advantages, but had one crucial drawback: it was extremely labour-intensive. This is evident from the large number of people occupied on one component in contemporary photographs.

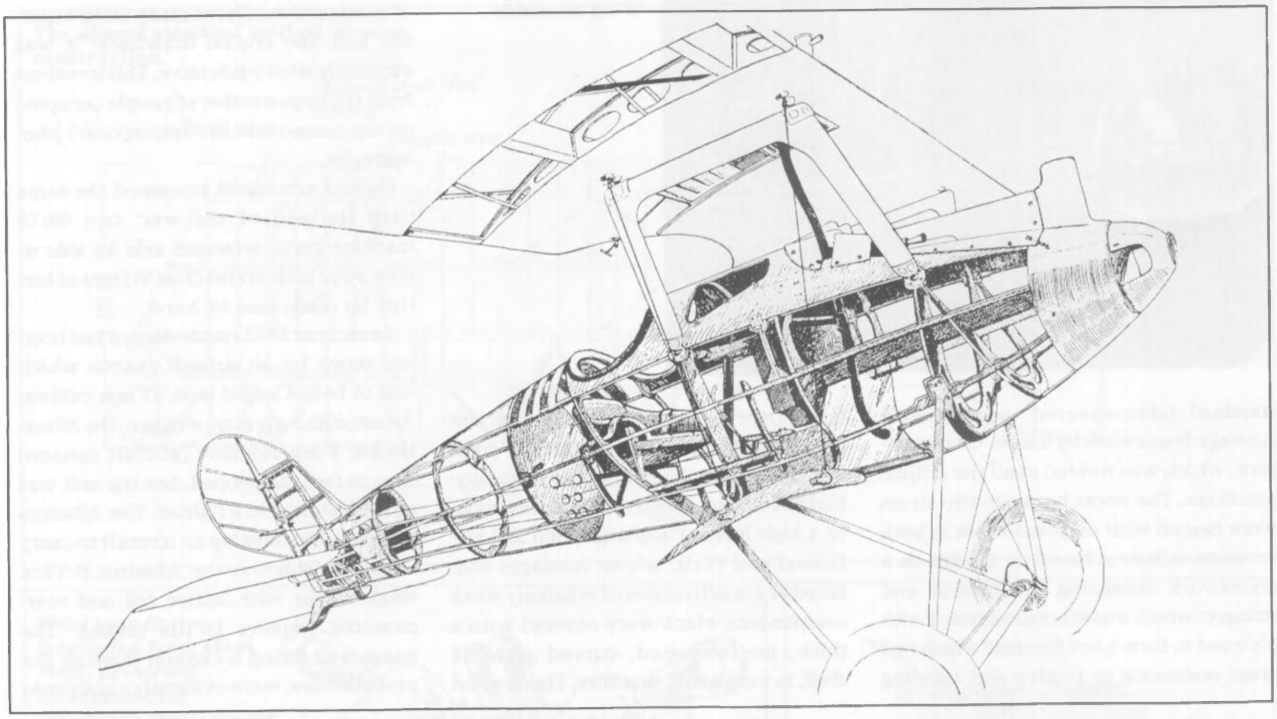
Fighter armament remained the same until the end of the war: two 08/15 machine-guns, arranged side by side at pilot's eye level and so close in front of him that he could load by hand.

As early as 1915 requirements had been laid down for an aircraft cannon which was to be not larger than 37 mm calibre. An astonishingly good weapon, the 20 mm Becker Fliegerkanone (aircraft cannon) was, in fact, developed, but the unit was never installed in a fighter. The Albatros company did develop an aircraft to carry a cannon; this was the Albatros D VI, a single-seater with lattice tail and rear-mounted Daimler D IIIa engine. The dangers of firing a cannon through the propeller disc were evidently considered

Pfalz wooden fuselage with steel-wire diagonal bracing (fabric covering removed).

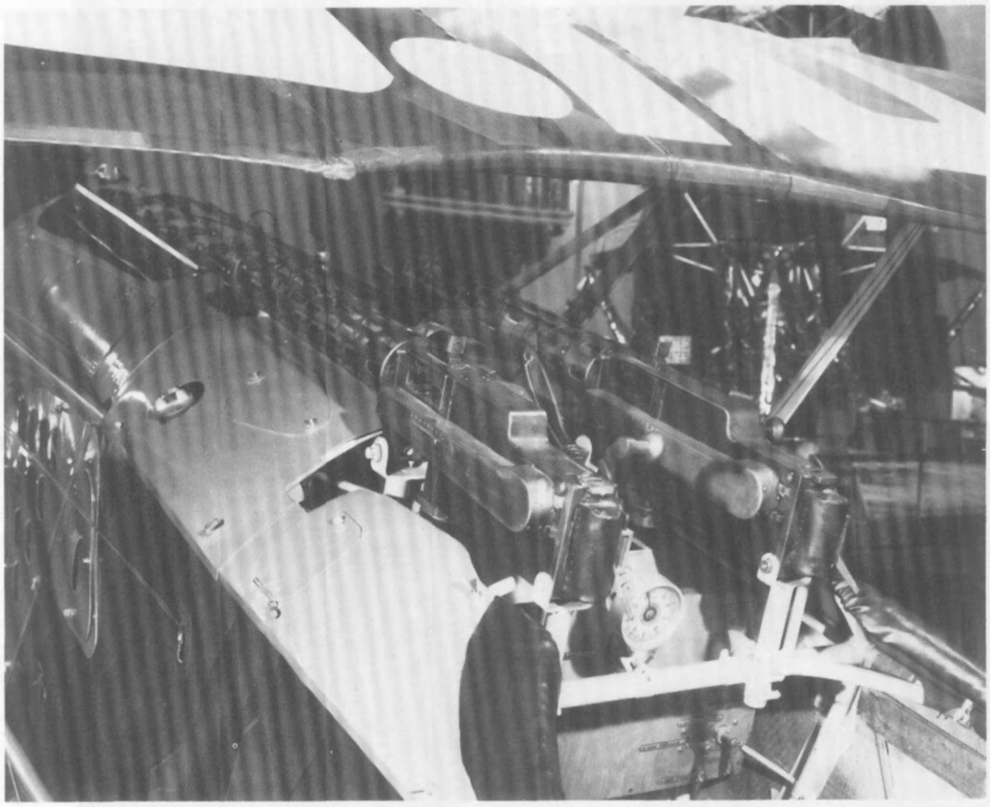


Pfalz fuselage construction.



Pfalz fuselage structure before attachment of skin.

Fokker D VII, twin machine-gun installation located directly in front of the pilot.



unacceptable. Work on this aircraft, which first flew in February 1918, was halted in June 1918.

The all-metal Ju D I and Do D I, which have already been mentioned, had hardly any influence on aircraft design at the time, but in later years their influence proved to be enduring. The structures are best documented here by a few photographs (below).

Great advances were made in the scientific analysis of airflow and structures during the war. As the Aircraft Department of the Flying Corps Inspectorate — the Idflieg — promoted the exchange of knowledge between the individual aircraft companies, and important progress was made at the experimental institutes. The results of practical testing and studies were published in the Technical Reports produced by the Aircraft Department. The Technical Reports in particular provided the aircraft industry with knowledge that was to be obtained nowhere else.

On 22 December, 1916, a discussion took place, chaired by the Commander of the Aircraft Department, Major Wagenführ, during which:

'an agreement was concluded concerning aircraft manufacturers' willingness to exchange freely the results of scientific testing and experiment. The information is to be published in a journal, the Technical Reports of the Aircraft Department (abbreviated T.B. — Technische Berichte), which is to appear at irregular intervals. These documents will be the property of the Aircraft Department, and will remain secret for the duration of the war.'

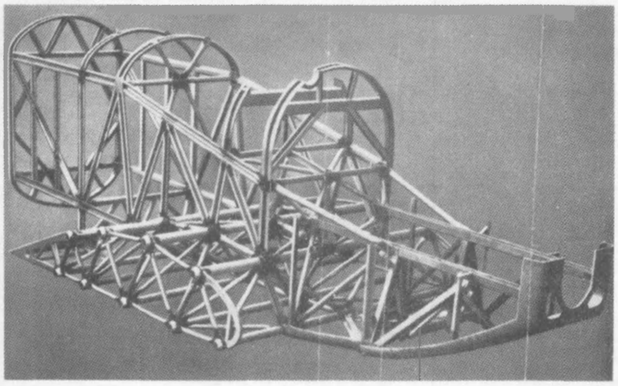
These reports, which were later collected in three volumes, included such contributions as: 'Calculation of air forces on a biplane based on the values for monoplane wings', 'Wind tunnel measurement on model wings of various aspect ratios', 'Stability calculation for wings plus tail and swept back wing with twist', 'Drag of struts', 'Aspects of exhaust manifold design', 'Duralumin as constructional material, including the effects of heat on fabrication and in operation', 'Loading and calculation of load multiples on army aircraft', 'New speed measurements', etc, etc.

The report 'New speed measurements' (T.B. Vol. III, Pp. 174-179) concerns this last, disagreeable subject, which has already been mentioned in the report on the second comparative fighter test series: the following is an extract:

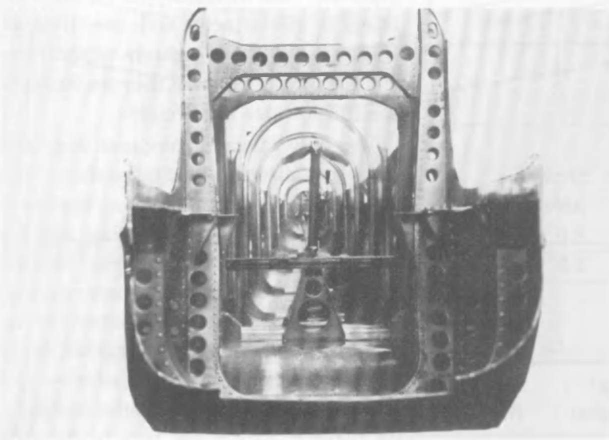
'The sole purpose of this report is to redress the present situation, in which absolutely no valid speed data exist which have been measured from actual flights. It is intended to provide an approximation of aircraft speeds, rather than their precise values. However, the documents presented here prove that the level flight speeds accepted as correct until now bear no relation to the true speeds achieved, with the result that the impressions given to us and to the enemy abroad are entirely erroneous. The reason behind this astonishing fact is that to date it has been impossible to measure airspeed accurately above 2,000 m altitude'

The results printed in the report are shown overleaf in diagrammatic form in the interests of clarity. The chart shows that the performance data usually quoted in aviation literature, probably based on company figures, bear little relationship to the truth.

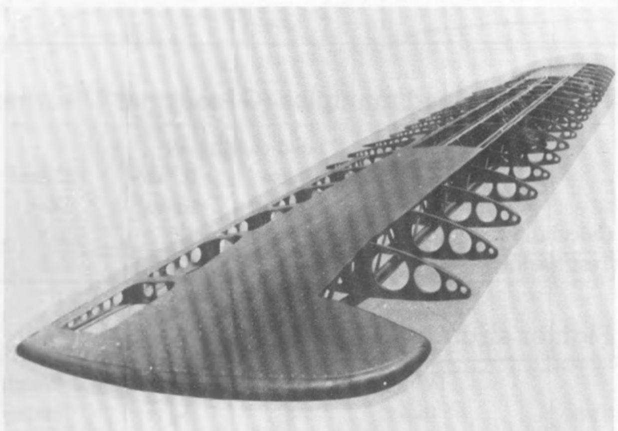
At Adlershof on 23 August, 1918, aircraft design engineers held a discussion on



Junkers single-seater, fuselage framework made of open dural profile strip, before attachment of corrugated sheet metal skin.

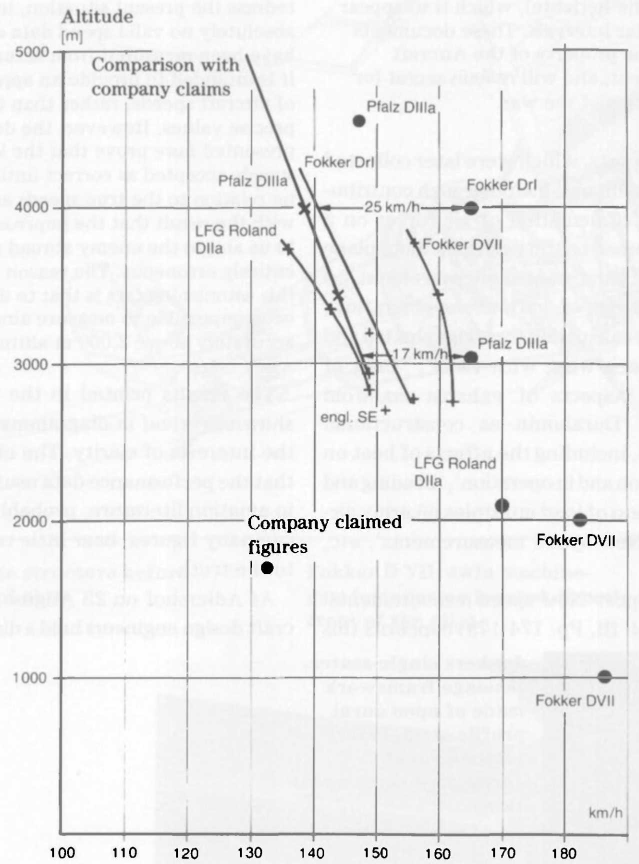


Zeppelin (Dornier) D I fuselage structure.



Zeppelin (Dornier) D I upper wing structure.

Level flight speeds measured by the flight testing department of the Idflieg, March/April 1918.



Prescribed load multiples (G loads) for D aircraft

	Load conditions			
	A case	B case	C case	D case
	Pull out	Glide	Dive	Inverted flight
Calculation	4.5	3.5	2.0	3.0
Test loading	6.0	4.0	2.0	3.5

Fighter aircraft 1916-18

Type	Wingspan (m)	Length (m)	Wing area (sq m)	Weight (kg) empty/loaded	Power (kW/hp)
Pfalz D III	9.4	6.9	22	700/920	120/160
LFG D VIa	9.4	6.3	23	675/875	120/160
Rumpler D I	8.4	5.8	16	630/845	120/160
Fokker D VII	8.9	7.0	20.5	700/900	120/160

acceptable stresses and safety levels. The discussion was also reported in the T.B.s. A distinction was drawn between the loads on which the calculations were based, and the loads which were to be employed for test purposes, beyond which airframe damage would result. The outcome was a grey area which made disputes inevitable concerning acceptability of aircraft and responsibility in accidents.

The term 'flying characteristics' occurred for the first time in these discussions. This was a concept which became the subject of increasing attention in later years, since shortcomings in these were the cause of most aircraft accidents.

The speaker, Captain Student, later to achieve fame as creator of the Fallschirmjagertruppe (paratroops), described:

'the poor handling of one aircraft which is popular at the Front: in really tight, full throttle turns the machine slips sideways and drops its nose. This fault can be alleviated, at least in part, by lengthening the fuselage. This example proves that the designer must bear in mind the necessity of retaining a certain minimum fuselage length during his commendable efforts to reduce weight. Other aircraft have the same, or similar faults. In all cases the aileron control pressure on the glide is very high.'

What Student described initially was a stall in the turn, resulting in the start of a spin. Because the tail was too short, or the fin too small, or both, the aircraft would then fall into a spin. Most aircraft of this era had the same fault, and countless fatal crashes were the result of this cardinal error. The relationship between this feature and the phenomenon was not realized until too late, and even then only by a few.

If we compare the training biplanes of 1933-34 — the Arado 69, the Focke-Wulf Stieglitz (Goldfinch) and the Heinkel Kadett — with the fighters of the First World War, we find that they are virtually identical in size and weight.

The only major differences were the enlarged tail lengths and tail surfaces. The later machines had ailerons on the lower wing as well as the upper wing, and the ailerons were considerably larger. But the trainers of 1933 were extremely easy and safe to fly, with very low control forces. Apart from the improved engines, these aircraft incorporated nothing which would not have been available to the designers of 1916-18, except the time to give due consideration to the results of tests, to study the results of their own experience and that of others, the time to try out new ideas, to make modifications and to refine

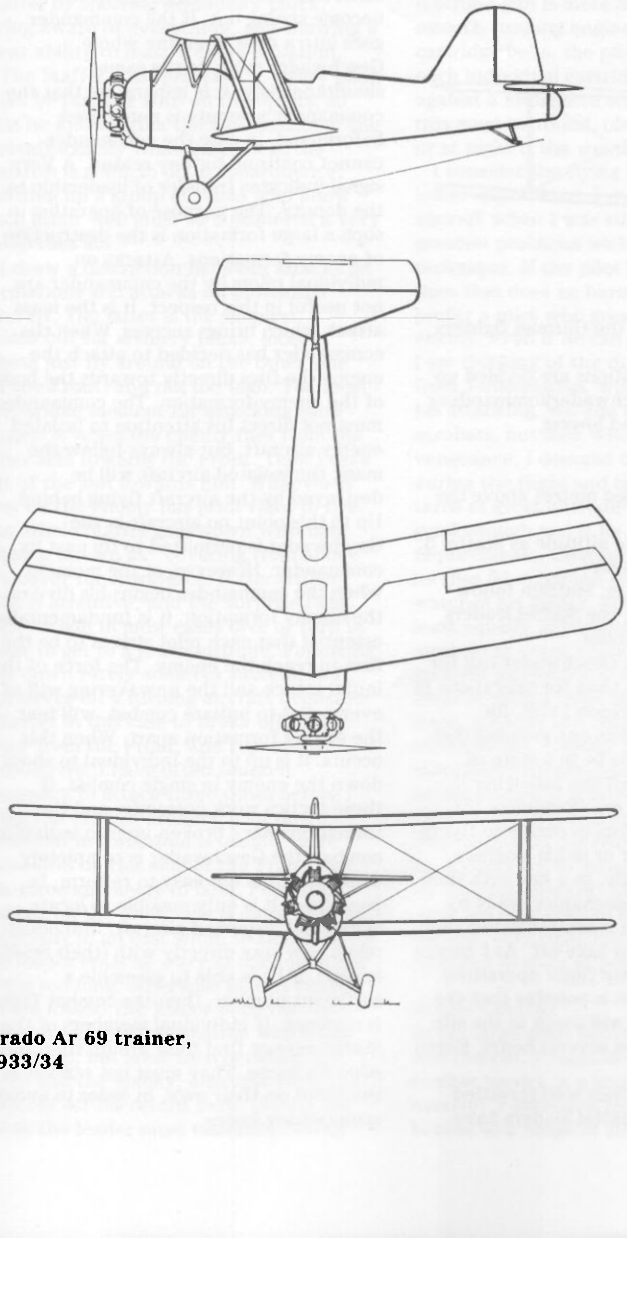
Trainer aircraft 1933

Type	Wingspan (m)	Length (m)	Wing area (sq m)	Weight (kg) empty/loaded	Power kW/hp
Ar 69	9.0	7.2	20.7	540/860	110/150
Fw 44	9.0	7.3	20.0	540/865	110/150
He 72	9.0	7.5	20.7	565/870	110/150

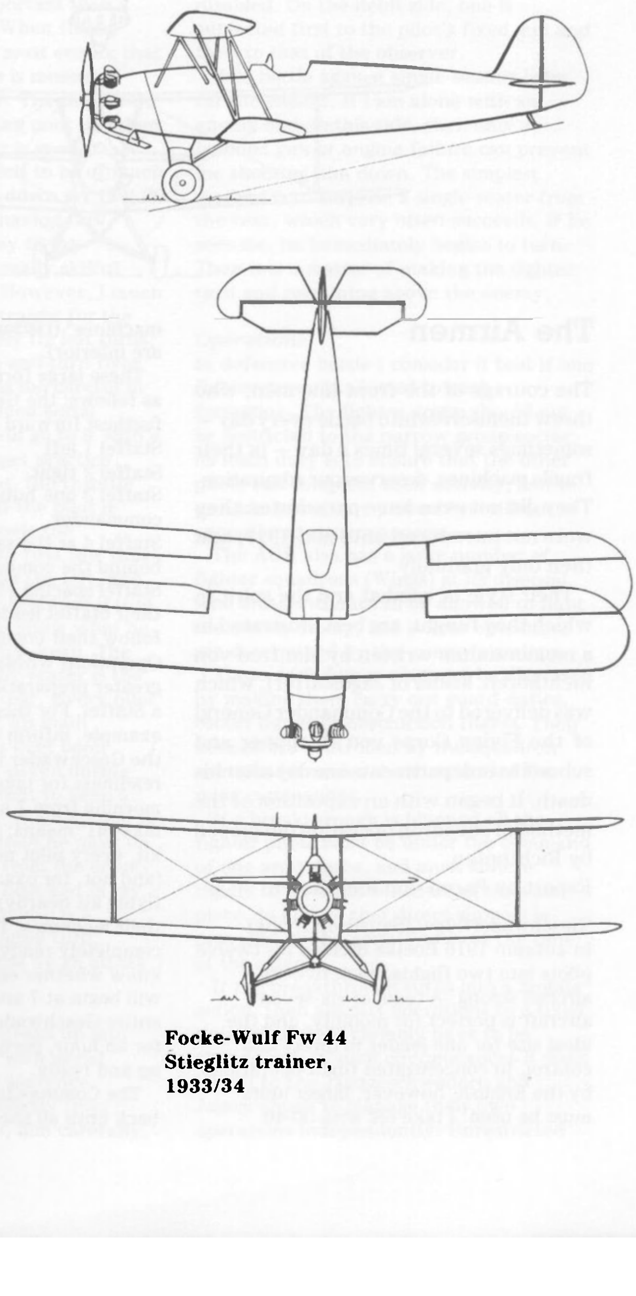
their products. Many years later the recourse to extending the fuselage to correct deficiencies, which was so successful with the Fokker D VII, was used again and with equal success on aircraft which subsequently turned out to be satisfactory, such as the Arado 65, the Focke-Wulf Fw 44 and the Messerschmitt Me 210, to name only three.

The cure for the excessive 'aileron control pressure', as lamented by Captain Student, had been known since 1914 — external and internal balances. But even 30 years later the exact size of the balance surfaces was still determined by practical testing, a time-consuming procedure in a period when time was either not available or not used. It was still not understood that small details could decide whether an aircraft would be a success or a failure within its own limits.

Those limits were dictated by the requirements laid down by the military, other peripheral conditions and the financial means granted to the project. To tread the tight-rope between the Utopian and the faint-hearted demanded a visionary mind which is very rare. To a designer who worked to a requirement for a single-seater based on an engine producing 80 hp, the idea of a similar machine with 200 hp power might have seemed presumptuous, but twenty years later the same could still be said, this time speaking of 800 hp and 2,000 hp.

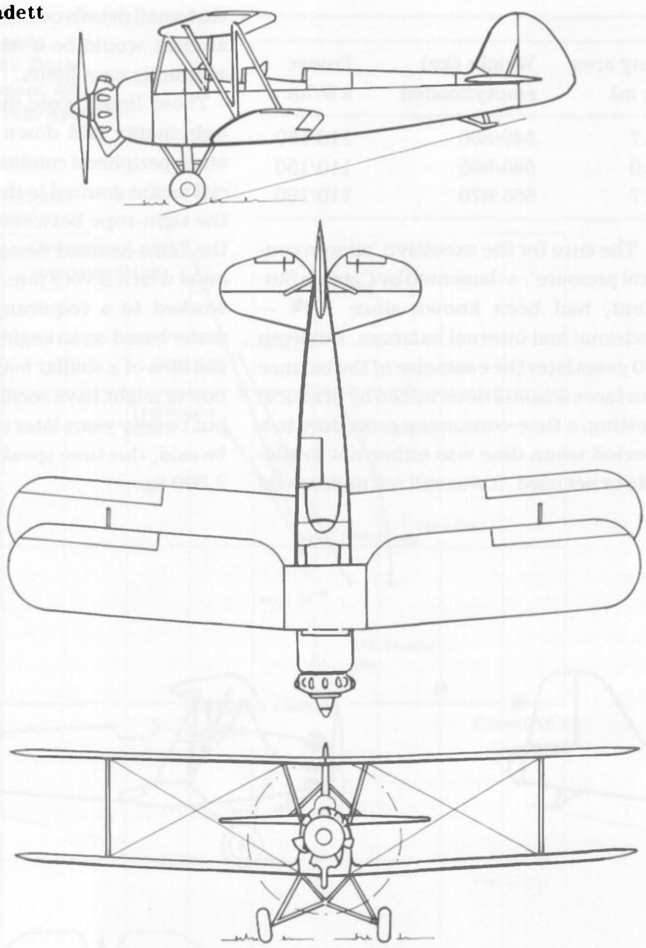


Arado Ar 69 trainer, 1933/34



Focke-Wulf Fw 44 Stieglitz trainer, 1933/34

Heinkel He 72 Kadett trainer, 1933/34



The Airmen

The courage of the front-line men, who threw themselves into battle every day — sometimes several times a day — in their fragile machines, deserves our admiration. They did not even have parachutes: they were not introduced until mid-1917, and then only gradually.

Their style of combat and the spirit in which they fought, are best illustrated in a memorandum written by Manfred von Richthofen, leader of Jagdstaffel I, which was delivered to the Commander General of the Flying Corps von Hoeppner and subordinate departments one day after his death. It began with an exposition of the method of squadron operation developed by Richthofen.

Report by Baron von Richthofen:

'Geschwaderfluge! (Squadron flying)
In autumn 1916 Boelke divided his twelve pilots into two flights, each five-six aircraft strong. A team of six-seven aircraft is perfect for mobility, and the ideal size for one leader to direct and control. In concentrated flight operations by the English, however, larger units must be used. I take off with 30-40 machines[4] (reason: the German fighters are inferior).

These large formations are divided up as follows: the Geschwaderkommandeur furthest forward and lowest,
Staffel 1 left
Staffel 2 right
Staffel 3 one hundred metres above the commander
Staffel 4 at the same altitude as Staffel 3, behind the commander
Staffel spacing 150 m. Staffeln follow their Staffel leader, the Staffel leaders follow their commander.
Operations within a Geschwader call for greater preparation than for operations in a Staffel. For this reason I will, for example, inform pilots one evening that the Geschwader is to be in a state of readiness for take-off the following morning from 7 am on. 'Readiness for take-off' means: pilots in complete flying kit, every pilot near or in his machine (and not, for example, in a hut with their flying kit nearby). Mechanics ready by their machines. The machines assembled, completely ready for take-off. As I cannot know whether enemy flight operations will begin at 7 am, it is possible that the entire Geschwader will await at the site for an hour, perhaps several hours, kitted up and ready.

The Commander flies well throttled back until all the Staffel leaders have taken up their prescribed places. To avoid confusion amongst the Staffeln, it is sensible for each Staffel to carry a distinguishing squadron badge. The commander's aircraft must be painted very conspicuously. . . in such a large group (30-40 machines) the Staffel leaders must maintain position throughout the flight. It is recommended also that each pilot has his own position within the Staffel, especially when some pilots are inexperienced.

If the Flight is experienced, precisely maintained positions are superfluous. I prefer to lead fighter squadron 11[5] like the field in a hunt; then it is immaterial whether I turn, dive, pull or push the stick. If the squadron is not so well trained, then good positioning is called for. If the Geschwader operation fails, then in 99 cases out of 100 it is the leader's aircraft which is at fault. He must match his speed to the slowest in his wing if an enemy formation is sighted, then the leader increases speed. This action must be recognised immediately by every individual in the Geschwader otherwise the very large group will become strung out. If the commander goes into a dive, then the whole Geschwader must do the same simultaneously. It is imperative that the commander's deputy is nominated beforehand, in case the commander cannot continue for any reason. A Very signal indicates transfer of leadership to the deputy. The purpose of operating in such a large formation is the destruction of enemy formations. Attacks on individual pilots by the commander are not useful in this respect. It is the mass attack which brings success. When the commander has decided to attach the enemy, he flies directly towards the body of the enemy formation. The commander must not direct his attention to isolated enemy aircraft, but always follow the mass; the isolated aircraft will be destroyed by the aircraft flying behind. Up to this point no aircraft in the Geschwader is permitted to fly past its commander. However, at the moment when the commander begins his dive on the enemy formation, it is fundamentally essential that each pilot strives to be the first to reach the enemy. The force of this initial attack and the unwavering will of every pilot to initiate combat, will tear the enemy formation apart. When this occurs, it is up to the individual to shoot down the enemy in single combat. If these tactics work correctly, and the formations have broken up into individual combat, the Geschwader is completely dispersed. It is not easy to re-form. In most cases it is only possible to locate occasional dispersed aircraft. Individual pilots now stay directly with (their Staffel leader). If he is able to assemble a sufficient number, then the combat flight is resumed. If individual members of the Staffel cannot find their group, then they must fly home. They must not remain at the Front on their own, in order to avoid unnecessary losses.

Immediately after each Geschwader operation it is essential to hold a discussion — this can be most instructive. Everything which occurs in the operation must be talked through, from take-off to landing. Many matters can be clarified if individuals are allowed to ask questions.'

So much — in abbreviated form — for the subject of Geschwader, or Wing, operations. There followed a section which is entitled:

'The leader
I demand the following of Ketten (Flight), Staffel (Squadron) and Geschwader (Wing) leaders:
He must be thoroughly acquainted with his pilots. As the Staffel is on the ground, so it must be in the air. These qualities, then, are pre-requisites:

1. Comradeship
2. Strict discipline

Every man must have unqualified trust in his leader in the air. If this confidence is lacking, then the chances of success are zero. The leader imparts this trust to his Staffel by showing exemplary pluck, being aware of everything, and showing a clear ability to master every situation.

The Staffel must practise . . . every pilot must be familiar with all the others, so that he knows from the movements of the aircraft exactly what the man at the controls is going to do in consequence, splitting up a group of pilots who know each other well must be considered a very dangerous act.

I draw a distinction between attacks on formations and attacks on individual aircraft. The latter is the simplest. I watch out for artillery pilots, most of whom just fly around on the other side (of the Front) and not too high. The most favourable moment for attacking such targets is when the enemy flies from the other side towards the Front. Then I dive out of the sun towards him. Whoever is first on the enemy has prior right to fire. The whole Staffel goes down with him. What is known as "covering from above" is a cover for cowardice. If the artillery pilot is attentive, and the surprise fails, then he will in most cases dive or turn in order to get to a lower altitude. Following him down rarely achieves success, as I can never hit a turning aircraft I consider it better in this case to break off, to fly away from the Front, and repeat the manoeuvre. I have often found it necessary to attack three times before I bring the English artillery pilot down.

Combat in formation is usually more successful on this side of the Front, as I can force an enemy to land. Formation combat on the other side is more difficult, especially in an east wind. In that case the leader must be wary of staying in the battle too long, otherwise he can expect severe losses. The leader must not fly through an enemy formation which has broken up, but must turn between the Front and the enemy, outclimb him, and then cut off his return path. During the battle the leader must maintain overall control of his own Flights and must know the whereabouts of the enemy formation at all times. This level of competence can only be achieved if frequent wing operations are carried out.

The ability to see is the main requirement and principal task of a Staffel leader.'

The next section discussed the following subject:

'How I train beginners
Under my leadership six Pour-le-Merite knights have shot down their first to their twentieth enemy. The main concern for a fighter pilot is the machine-gun. He must become familiar with it to the point where he recognises by the nature of the jam why it has happened. When I come home with a jammed gun, I can usually tell the fitter exactly where the fault lies.

It is the pilot, not the weapons foreman or the mechanic, who is responsible for the operation of his machine-gun. No gun jams itself! If a fault occurs, then it is the pilot alone who is the culprit. An efficient machine-gun is more important than a smooth-running engine. When fitting cartridge belts, the pilot must ensure that each individual cartridge is measured against a millimetre scale. The time to do this must be found, (during poor weather, or at night if the weather is good).

I consider the flying itself to be of much lower importance. I shot down my first 20 aircraft when I was still having the greatest problems with my flying technique. If the pilot is really skilful, then that does no harm. However, I much prefer a pilot who goes straight for the enemy, even if he can only fly left turns; I am thinking of the dive-and-turn flyer from Johannisthal, who is too careful in his attacking. We don't need aerial acrobats, but men who will go to it with a vengeance. I demand target practice during the flight and tight, full throttle turns at great altitude[6]. If the pilot is good enough and if he meets the requirements, then for the first few times he flies 50 m behind me on the left, and watches his leader. For a beginner it is at least equally important to know what he must do to avoid being shot down. The greatest danger for a single-seater is the surprise attack from the rear. Every pilot must, without fail, direct his main attention aft. Nobody has ever been surprised from the front. (Even during actual combat it is important to keep a careful watch to the rear. If a beginner is surprised from the rear, then he must on no account try to escape from the enemy by pushing forward. The best and in my view the only correct response is a sudden, very tight 180 degree turn, followed as soon as possible by an attack.)

Single Combat
Every large-scale battle breaks up into solo combat. I could deal with aerial combat tactics in a single sentence, namely: 'I approach the enemy from behind to a range of 50 m, aim carefully, then the enemy falls'. When I asked Boelcke for the secret of success, he dismissed me with those words. Now I know that this is the entire secret to shooting aircraft down. Nobody needs to be a brilliant pilot or a wonderful shot; you just need the courage to approach the enemy extremely closely. The only distinction I make is between single-seaters and two-seaters The two seater should be attacked directly from the rear at great speed. You can only evade the machine-gun of the skilful observer by remaining calm and taking the observer out of the fight with your first shots. If the enemy turns, I take care never to get above the enemy aircraft. Protracted combat against a maneouvrable, fully armed two-seater, involving many turns, is the most difficult. I fire only if the enemy is flying straight, or when he is just initiating a turn. Never exactly from the side or when the aircraft is banked over. I consider it very dangerous to attack a two-seater from the front. First one very seldom hits the enemy, and the enemy is virtually never completely disabled. On the debit side, one is subjected first to the pilot's fixed gun and then to that of the observer.

Solo battle against single-seaters is by far the easiest. If I am alone with an enemy and on this side, then only a jammed gun or engine failure can prevent me shooting him down. The simplest method is to surprise a single-seater from the rear, which very often succeeds. If he sees me, he immediately begins to turn. Then it is a matter of making the tighter turn and remaining above the enemy.

Operations
In defensive battle I consider it best if one fighter group is allotted to each formation. The fighter group should not be restricted to the narrow group sector; its main duty is to ensure that the other pilots can complete their activity, and to provide immediate protection to them in exceptional circumstances.

The AOK also has a large number of fighter squadrons (Wings) at its disposal, who must without fail be allowed to hunt the enemy freely, and whose operations are determined by the enemy's actions.

These AOK forces must not be dispersed by making them carry out guard duties, escort duties or obstruction flights. Their actions are controlled by the squadron commander under the direction of the wing commander.

If a breakthrough is planned all the fighter pilots must be under the command of one army force, and must adhere rigidly to an exact schedule of time and place, to ensure that direct support is provided by the aerial forces at the time of the attack.

If the breakthrough turns into a mobile action, then aircraft operations to a fixed time schedule invariably have to be abandoned. In such circumstances it must be left to the Jagdgeschwadern and Jagdgruppen to manage their own operations independently. Unrestricted

combat does not include fighting neighbouring armies or base stations; it means destroying the enemy on the infantry battlefield, at the lowest possible altitude, and flying as frequently as one's Staffel can possibly manage.
signed Baron v. Richthofen'

The End of the Luftwaffe, 1918

Soon the aircraft of the German fighting forces were to be delivered up to the victorious powers, broken up, scrapped and burned; fourteen or fifteen thousand of them. When the smoke had cleared, when not one single aircraft remained to carve its way across the sky, there was nothing left but the memory, a memory which turned into a romance. A romance, which spread far across the world and still lives on.

More than 50 years later Snoopy, America's national mascot, still dreams of fighting the Red Baron high over France in his Sopwith Camel, and finally getting the chance to bring him down.

Even today if you order a Cappuccino or an Espresso in Italy, you will receive little packs of sugar with the pictures of the First World War fighters on them: the Albatros D V, Sopwith Camel, Spad S 13, Fokker D VII.

The Period After the First World War, 1919-1928

New Aircraft Built According to the Terms Laid Down After May 1922

Ban on all forms of Aviation by the Treaty of Versailles

The post of Commander General of the Luftstreitkrafte (Aerial Forces) (KoGen-Luft), General von Hoeppner, was cancelled on 21 January, 1919, immediately after the election of the parliament of the Weimar Republic. The Head of the KoGen-Luft Staff, Colonel Thomsen, became Head of the Air Division A7L in the Prussian War Ministry. His colleague, Captain Wilberg, worked out a plan for a postwar aerial armed force, which Major General von Seeckt, military expert in the peace negotiations, wanted to include in the Treaty conditions. No decision had been taken at this point about a postwar army, and nobody in Germany believed that complete aerial disarmament would take place. But the Treaty of Versailles, signed on 28 June, 1919, called for the dissolution of all flying corps, to be completed two months after the Treaty came into force — 10 January, 1920. Every item of military aircraft material had to be relinquished to the Allies. These measures were to be monitored by the Inter-Allied Aeronautical Commission of Control. A small armed force, consisting of a 100,000 man army and 15,000 man navy, was allowed to remain, and the type and number of every permitted item of equipment was laid down. There was no mention of aircraft. If the rules were to be followed to the letter, it would not even have been possible to undertake any theoretical work on airborne apparatus within the Reich.

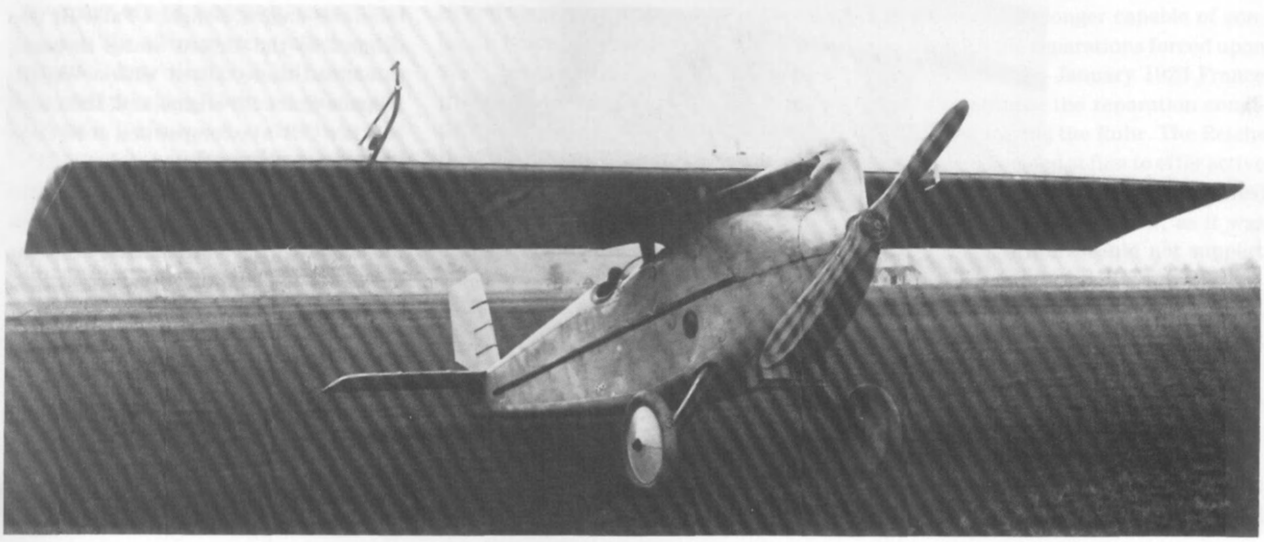
General von Seeckt, who on 24 November, 1919, had become Head of the Reichswehr Personnel Office, set up a special departmental section within the Forces Office on 1 March, 1920, under the designation Luftschutzreferat (Air Defence Section) TA (L) to deal with all questions relating to aviation. Head of the new section was to be Captain Wilberg. Within the Weapons and Apparatus Inspectorate (In WG) a 'Flight Technology' section was set up under Captain Student, whose task was to draw up plans for (subsequent) development and testing. These measures only served to keep a small number of armed forces personnel familiar with aviation matters; no actual activities were permitted, and would inevitably have led to problems at home and abroad.

On 5 May, 1922, three and a half years after the armistice, Germany was permitted to resume work on aircraft and aircraft equipment, but only on civil aircraft. The armed forces were strictly denied access to such machinery, and industrial companies were only allowed to do such work under the conditions laid down. These conditions were dictated to the Reichs government in a memorandum from the ambassadors' conference held on 14 April, 1922. Aircraft performance was strictly defined, to ensure that they would remain absolutely harmless:

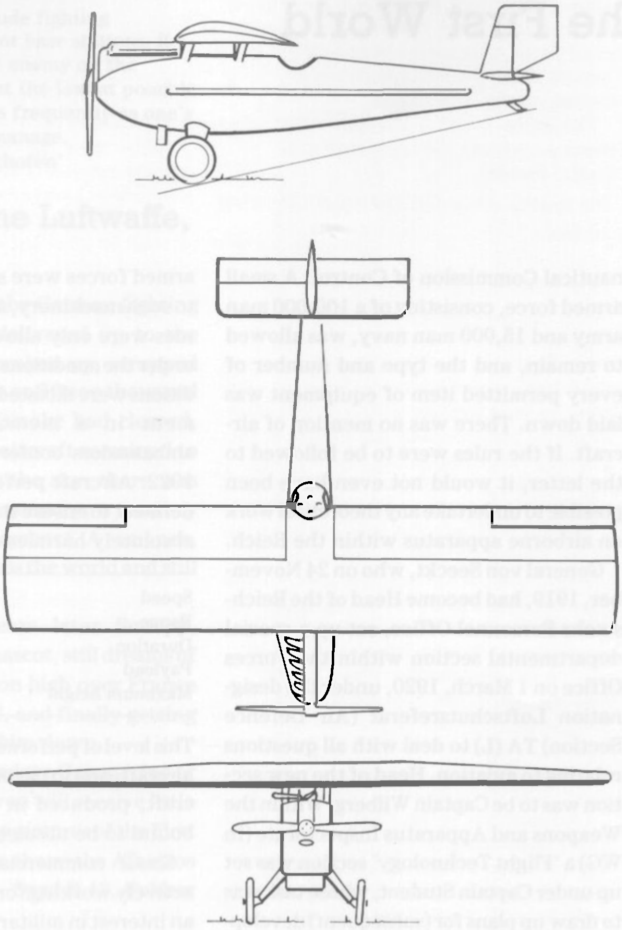
Speed	170 km/h
Range	300 km
Duration	2½ hr
Payload	600 kg
Maximum height	4,000 m

This level of performance ensured that any aircraft, and in particular any military aircraft, produced in the year 1922 were bound to be obsolete.

Small commercial groups had been actively working for countries which had an interest in military aviation but had little experience in such matters; these groups, which constituted the aviation industry at the time, had to work in secret, but had long since advanced past the state of technology which had been prescribed. Aircraft were being designed in Germany,

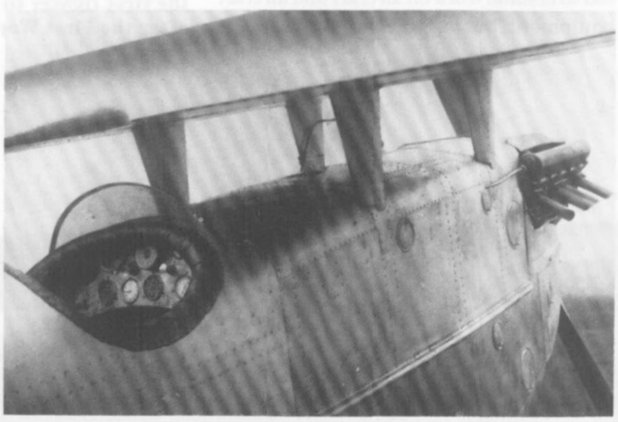


Dornier Do Falke fitted with BMW IVa, the first fighter to be built in Germany after the First World War.



Dornier Falke

Wingspan	10.0 m
Length	7.45 m
Wing area	20.0 sq m
All-up weight	1,200 kg
Hispano-Suiza	300 hp



Dornier Falke. Attachment of the one-piece wing to the fuselage.

manufactured in component form, then shipped abroad for final assembly. Among the clients were such unexpected customers as the United States, to whom the firm of Caspar in Travemünde sold two submarine-borne aircraft. A similar machine had been built during the war at Hansa-Brandenburg, under the direction of Ernst Heinkel. Heinkel also directed the work at Caspar, and this marked Heinkel's resumption of work on aircraft after the war. Unfortunately it has proved impossible to establish whether the contract was awarded by the US Navy direct or by a middleman, as had occurred in another case.

Around this time Dornier also supplied an aeroplane to the United States, a single-seat fighter built entirely in duralumin, known as the Do Falke (Falcon). It had been produced by the procedure just described. The design work was done in the Seemoos offices near Friedrichshafen. It is likely that the components were also made in Germany. The machine was assembled in Rohrschach in Switzerland, and the first flight took place on 1 November, 1922, at Dübendorf in Switzerland.

The Do Falke was probably the first fighter aircraft developed by German engineers after the war. Claudius Dornier's colleagues at the time included Richard Vogt, director of Hamburg Flugzeugbau from 1933 to 1945, and Alexander Lippisch, for many years director of engineering at the Rhon-Rossitten Company, which subsequently became the German Gliding Research Institute. It was Lippisch who developed the tailless rocket-powered Me 163 fighter in 1942.

The Falke was powered by a 300 hp Hispano-Suiza engine. The US engine manufacturer Wright Aeronautical Corporation, which had obtained a licence to build this engine, bought a Falke. It was shipped to the United States in parts, assembled there, fitted with a Wright-Hispano-Suiza H3 engine, and then took part in a US Navy competition at McCook Field in April 1923. From first flight to demonstration in America took six months — an astonishing feat. The Navy then took possession of the aircraft. However, the hoped-for engine contract for the Wright-Hispano-Suiza did not materialise.

The design was a further development of the principles adopted for the first time by Dornier on the Do D I biplane in 1918. In deference to the successful Fokker D VIII concept, the Falke was a cantilever high-winger. In many respects the aircraft represented a real advance, and was many

Fokker D.XIII, the first fighter aircraft in service with the Reichswehr.

years ahead of the fighters of its time.

Great attention had been paid to the Falke's aerodynamics, and it was built entirely in flat sheet metal. The tail surfaces and wing were entirely cantilever, and the unbraced cantilever undercarriage was a particularly noteworthy innovation. The connection between wing and fuselage consisted of four streamlined cantilever struts, which were built as part of the wing and absorbed part of the bending loads. The struts were attached to the fuselage by detachable steel bolts. The one-piece wing had two spars, and was skinned with sheet dural as far back as the rear spar, aft of which it was fabric covered. The ailerons were rather small, and it is likely that poor roll response prevented the aircraft becoming a successful fighter. It is surprising to discover that the completely new form of undercarriage was not imitated throughout the world immediately; perhaps it was too advanced.

Early in 1925 Dornier entered the Falke, or Do G, as it was also known, in a competition for the Chilean armed forces (Army and Navy). The aircraft was shipped from Hamburg to Buenos Aires in the Stinnes steamer *Belgrano* in January 1925, together with another Dornier aircraft: a flying-boat powered by a 360 hp Rolls-Royce Eagle. After demonstrating the machine to the Argentinian Army at Buenos Aires, the pilot, von Schoenebeck, a former fighter pilot in the Richthofengeschwarder, flew to Santiago de Chile via Mendoza, which meant that he had to cross the Andes, more that 6,000 m high.

The technical director of this South American expedition was Herr Feucht, who accompanied Amundsen on his attempted flight to the North Pole in summer 1925, flying a Dornier Wal.

The other main contestant in the Santiago competition was a US Curtiss P-1C fighter, but the Falke held the advantage. The Curtiss was piloted by Marine Lieut Doolittle, from the Navy Aircraft Factory in Philadelphia, who was later to become an Air Force General in the Second World War. Relations between the two competitors could hardly have been more friendly; indeed, they even exchanged their machines, which today sounds virtually unbelievable.

In 1922, when the Do Falke was being built, Junkers designed another single-seater. This also was a cantilever high-winger, designed in Dessau and built in the USSR. The H 22 was not the equal of the Do Falke in respect of aerodynamic quality. Junkers had allowed himself to be seduced away from the cantilever low-wing layout which he had correctly pursued with the J 7 and the J 9 (D I). Who persuaded him, nobody knows.

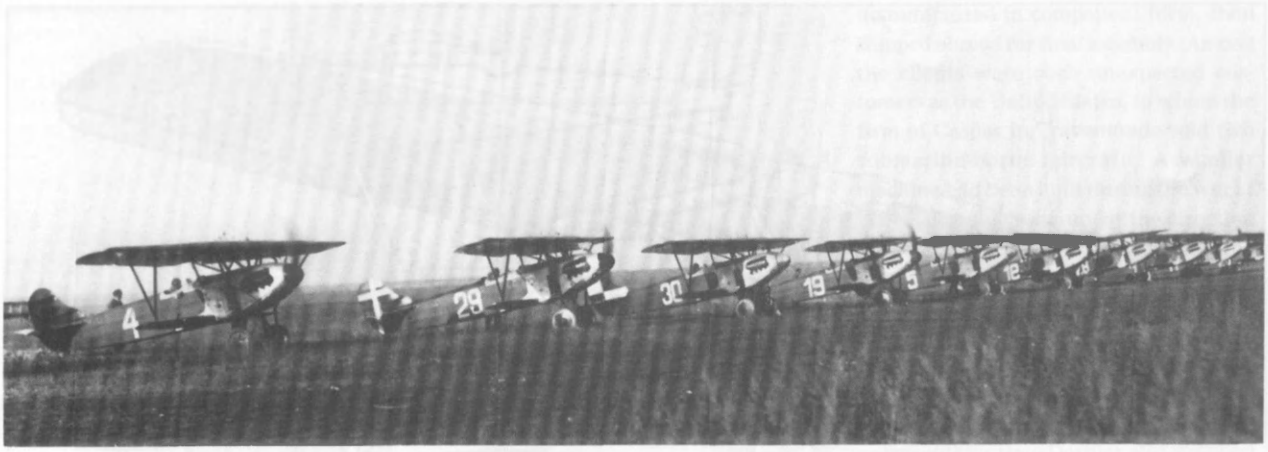
With the exception of the Do Falke, which was built under contract to one of the victorious powers, the construction of real fighter aircraft in Germany, *i.e.* aircraft whose performance went far beyond the values laid down in the 'terms', had not yet begun.

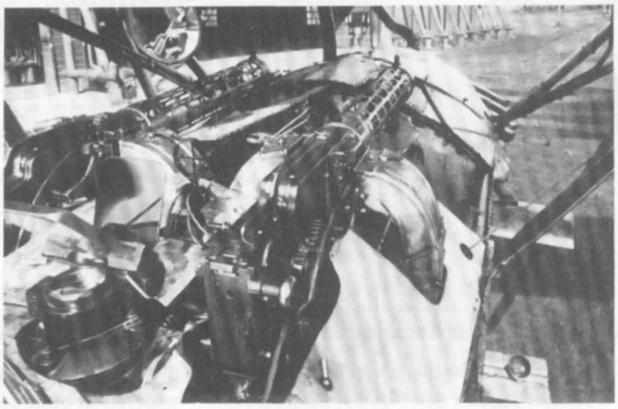
The Ruhr Crisis of 1923 and the procurement of the Fokker D.XIII

Inflation was galloping ahead. Something which cost thousands yesterday cost millions today, and billions the day after that. Everything was in short supply. In 1922 Germany was no longer capable of continuing with the reparations forced upon it in Versailles. In January 1923 France sought to enforce the reparation conditions by occupying the Ruhr. The Reichs government decided at first to offer active resistance. The Reichswehr (armed forces) felt strong enough to do this, as it was thought that Britain would not support France.

The Reichswehr knew that no army, regardless of size, could manage without aircraft, and for this reason 100 fighter aircraft of the D.XIII type were ordered from Fokker, which was by now a Dutch company.

It is impossible to avoid thinking that Fokker did not begin work on the D.XIII

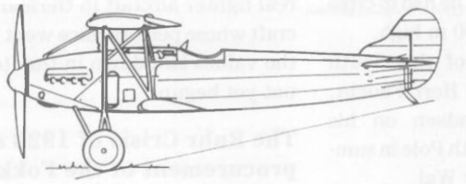




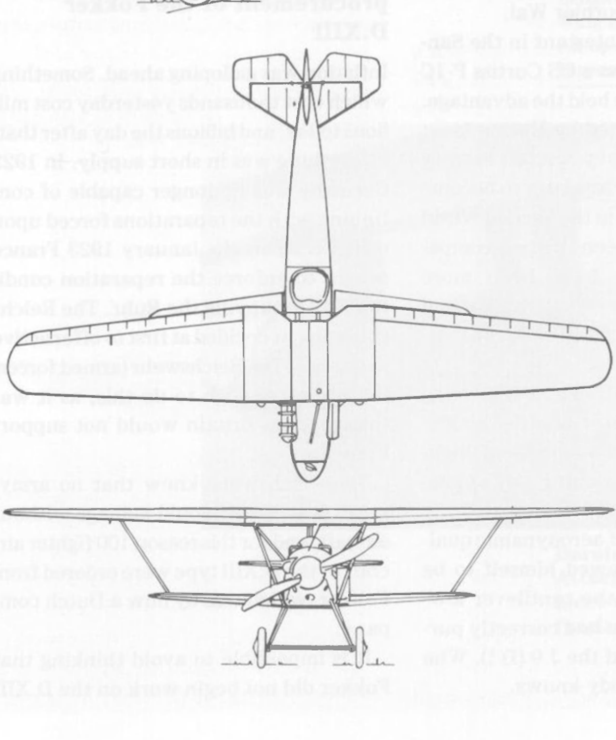
Fokker D.XIII in the German training and test centre at Lipetsk in the USSR.

Fokker D.XIII. Machine-gun installation with reflector-type sight.

Fokker D. XIII



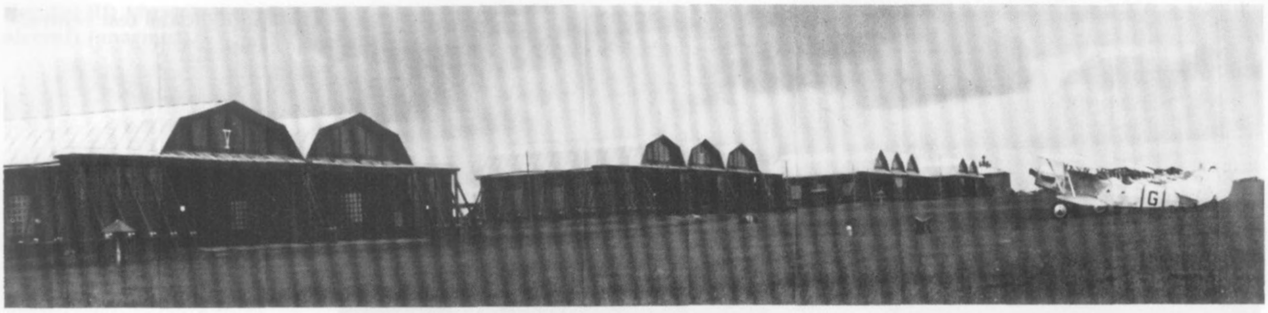
Wingspan	11.0 m
Length	7.9 m
Wing area	21.5 sq m
All-up weight	1,650 kg
Napier Lion XI	450/600 hp



until he had been approached by Germany, and then done it at his usual high speed. The first flight took place on 23 September, 1923. The aircraft was probably the best in the world around this time, and it was used to set up four World Speed Records.

The Fokker D.XIII was an unbraced biplane with V interplane struts between upper and lower wing whose task was to absorb the torsional forces of the upper wing. The upper wing was much larger in area than the lower wing. The fuselage was built by the steel tubing/fabric method which Fokker had employed from the very start, while the wings were entirely skinned with plywood. The wing attachment was exactly the same as that on the Fokker D VII dating from 1918, which had stood the test of time. The radiators projected out of the fuselage sides at the wing root position, with no aerodynamic refinement, as on the German fighters of 1916. The undercarriage was standard 1917-18 style, but the engine was thoroughly up-to-date: it was the 450 hp Napier Lion, a twelve-cylinder unit of W-configuration, and without doubt the best aircraft engine of its time. The following extract from the diary of a fighter pilot trainee gives some indication of the machine's handling in the air:

1. 'Fokker D.XIII control pressures are almost zero.
2. In steep turns it tends to drop its nose, and falls vertically when banked hard over.' We would say: drops the inboard wing in a turn. Bear in mind what



Aircraft hangars at the Lipetsk training and test centre, with Heinkel HD 17s on the right.

Richthofen said about 'full throttle turns at great altitudes'.

3. 'A snap roll produces three rotations, followed by a spin'. We would say: snap roll produces a horizontal spin followed by a normal spin.
4. 'Spin to the left: machine drops into a flat spin'.

All in all: not particularly desirable qualities when pushed hard.

The armament consisted of two 08/15 machine-guns, mounted above the engine firing through the propeller disc.

When the idea of active resistance was dropped, nobody knew what to do with the aircraft which had been ordered. An attempt to sell them to Argentina through the Stinnes organisation, which dominated German economic life at the time, failed. However, with the new economic relations which resulted from the signing of the Russo-German Treaty of Rapallo (16 April, 1922), the possibility arose of establishing a centre for German fighter-pilot training and practice in the USSR using these aircraft.

The Lipetsk Training and Proving Centre

Lipetsk subsequently turned out to be an important factor in the preparations for rebuilding the Luftwaffe, and for this reason it is appropriate to mention a few details of the Centre here.

Discussions on possible German-Russian co-operation in military matters had been under way as soon as the preliminary negotiations in Rapallo had started. The result was the establishment of a pilot's training and practice centre at Lipetsk, a medium-sized city on the River Voronezh, 360 km southeast of Moscow. In 1924 the installations were extended, and in summer 1925 the first training course of practice for one-time fighter pilots was completed.

Such a facility was a basic necessity, since the pilots, who had not flown for years, would not be capable of anything without completing a refresher course. In any case, a new generation of pilots would be needed in few years time if large-scale rearmament, long-term plans for which were made around this time, was to take place.

A further purpose of the Centre was to experiment with new forms of operational flying. The Treaty conditions laid down that the results of this work were to be made available to the Red Army in return for guaranteeing the land and the installations without restriction.

The airfield was also intended for observer training in addition to fighter-pilot training. In other words, for gunners in two-seater aircraft. There were as many observers as pilots at the Centre. The idea of the two-seater fighter *i.e.* a fighter which could be defended to the rear, had constantly occupied the minds of aviation tacticians and strategists, since this would deny an attacking aircraft the main direction for firing.

With the Fokker D.XIII Germany had a reasonably satisfactory number of single-seat fighters. The next step was necessarily a two-seater to fulfil the dual role of reconnaissance and two-seat combat aircraft; something akin to the C-type of the previous war. To this end Heinkel built the HD 17, powered by the same British engine as the Fokker D.XIII. It was constructed under the strictest secrecy, as the HD 17 contravened the terms in virtually every respect. It was destined to be the standard two-seat training aircraft at Lipetsk for many years.

In 1925 it was still being claimed that Lipetsk was used solely for training flight personnel, in spite of its code name Wivupal (Wissenschaftliche Versuchs und Prüfanstalt für Luftfahrzeuge — Scientific experimental and testing institute for aircraft). No aircraft or machines were being tested there. After all, why should aircraft be tested if there were no core of crew personnel? We might equally ask the question the other way around.

Over its eight years of use by the Reichswehr, Lipetsk trained about 120 pilots and around 100 observers. This amounts to 15 pilots and a dozen observers per year; hardly an overwhelming number. However, the time which was available for training was quite short. It began after the May floods which followed the snow thaw, and ended with the first snowfalls, which set in at the start of October.

The first trainees who completed the refresher courses were former First World War pilots, followed by new pilots who had received their basic training at flying schools in the Reich, and then obtained their full fighter-pilot qualification at Lipetsk. These pilots were uniformly high quality. The list of names of those who

Lipetsk flight and test centre. The camp.

went to Lipetsk sounds like a roll-call of subsequent leaders in the Luftwaffe, the testing centres and the Air Ministry.

The fighter-pilot training centre at Lipetsk was not developed until the end of the great period of inflation, which was stabilised in November 1923. At the end a trillion paper Marks, *i.e.* one thousand billion Marks, were equal in value to one gold Mark. Without stabilisation the enterprise would probably not have been possible. The financial means which were invested at the start were amazingly small. It is said that the sum did not exceed three million Reichsmark, which was the new currency introduced after the period of inflation.

In the following years the budget for Lipetsk was two million Reichsmark per annum, which included expenditure on material, personnel and flying training.

The secrecy surrounding Lipetsk was maintained to the utmost degree. The activities, although undertaken with the full knowledge of the Reichs Government, could have led to severe political difficulties at home and abroad if news of them had reached the public. All personnel received aliases and replacement passports made out in the new name for the period of their stay in the USSR. The documents were surrendered on their return to Germany. The Moscow Centre (ZMO), the point of liaison with the Russian Government, had no official contact with the German Embassy. It was run by Colonel Thomsen, also operating under an alias, who had been Chief of Staff of the Idflieg in the previous war.

The administration staff and the core of the German personnel who stayed in Lipetsk throughout the winter, were accommodated in the fortified buildings of a former factory for alcoholic drinks, hence the name Vinograd. A number of block houses were also built. The bulk of the flying crews, who came to Lipetsk for the summer months for training and testing, lived in a well equipped barrack camp. The Germans could move about unhindered, could go bathing along the river Voronezh. The only Russians who had access were those who worked in the German installations. The number of Russian personnel was large. Manual work and auxiliary assistance of all kinds were done by the Russians, in order to keep the number of those 'in the know' to the minimum. The only Germans who came to Lipetsk were high-calibre men. They were not permitted to inform their families about where they were staying, nor what they were doing. The post was taken to berlin via a publishing house, whose postal traffic was so gigantic that the Lipetsk post went unnoticed. And all this functioned perfectly; there were no press leaks, no attempts at blackmail; it all sounds rather surprising today. The espionage services of some foreign countries must have gained some information, but their questions to German embassies were answered with unknowing shrugs of the shoulders.

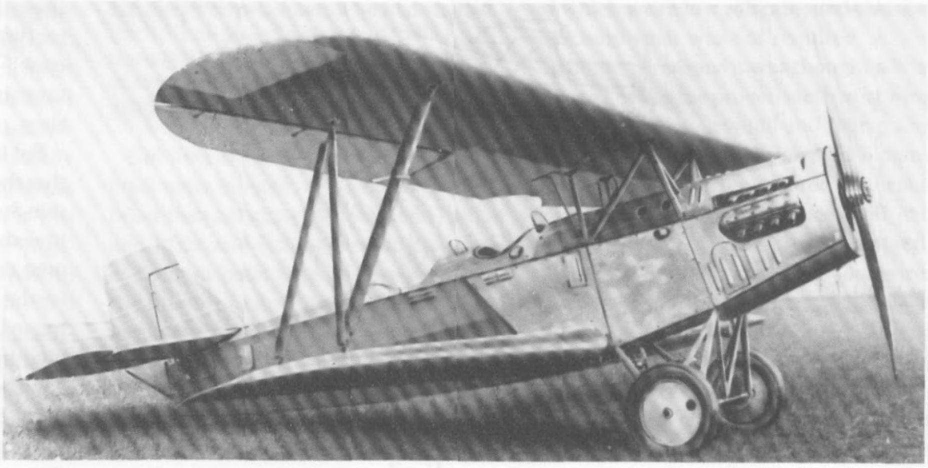
After about 1928, when the International Military Control Commission (IMKK) were no longer constantly wandering around, new aircraft and new accessories and new items of equipment gradually started to be developed. Final testing always took place at Lipetsk. At first aircraft had been packed in crates, shipped to Leningrad by sea and thence to Lipetsk, but now they were flown via Riga, stripped of all military fittings and equipment.

No military equipment was installed at the aircraft factories. The machines were fitted out in a special, sealed hangar belonging to the German Aviation Industry Association, another cover organisation, in Berlin-Staaken. After everything had been tested on the ground, all the military equipment was again removed. Aircraft, equipment and testing personnel then went their separate ways to Russia.

The testing of German-made military components did not begin in earnest until around 1930, as the developments begun in 1923 had not been far enough advanced for testing. Equipment for fighter aircraft including gun mounts, gun sights, bombs for infantry combat from single-seat and two-seat fighters, and corresponding container and jettison mechanisms. It was here that the basic form of the Jabo (Jagd-Bomber — fighter bomber) was laid down. A report dated November 1931 emphasised that using fighters to drop bombs was substantially more effective that strafing with machine-guns. It seems likely that relatively little weapons testing was done, even though there was an urgent need for it. Machine-guns firing through the propeller disc resulted in propeller damage again and again. In his diary, a fighter pilot trainee from the Lipetsk school recorded that eight shots had passed through his propeller during three of his practice flights in the course of two and a half months.

The aircraft used at the fighter-pilot training centre and also many of the newer aircraft were armed with the 08/15 machine-gun dating from the First World

Heinkel HD 17 two-seat combat aircraft (unarmed).



War. The slightly more modern 08/18 machine-gun was installed in only a few exceptional cases. All new fighter aircraft were tested at Lipetsk until it was abandoned in 1933. At first all testing was done at Lipetsk, but later only the military aspects. It seems likely that the leaders of the German armed forces had always planned to abandon the Lipetsk facility around this time; naval leaders were informed on 16 January, 1933 that the training of naval pilots at Lipetsk would not be possible, 'as the R. Station will be abandoned in Autumn 1933'.

The new government, as one can easily imagine, finally wielded the axe. Relations between the Germans and the Russians at Lipetsk, which seem to have been entirely pleasant for a long time, deteriorated severely in the course of the summer of 1933. The diary of the fighter pilot trainee already mentioned included the following entries:

'21 July — provoked the Russians. Mixing with Russians forbidden.
25 July — Negotiations for transfer to the Russians carried out by Wilhelm Speidel[7].
14 August — No more flying by order of the Reichs Government. Dates for leaving 20 and 22 August.'

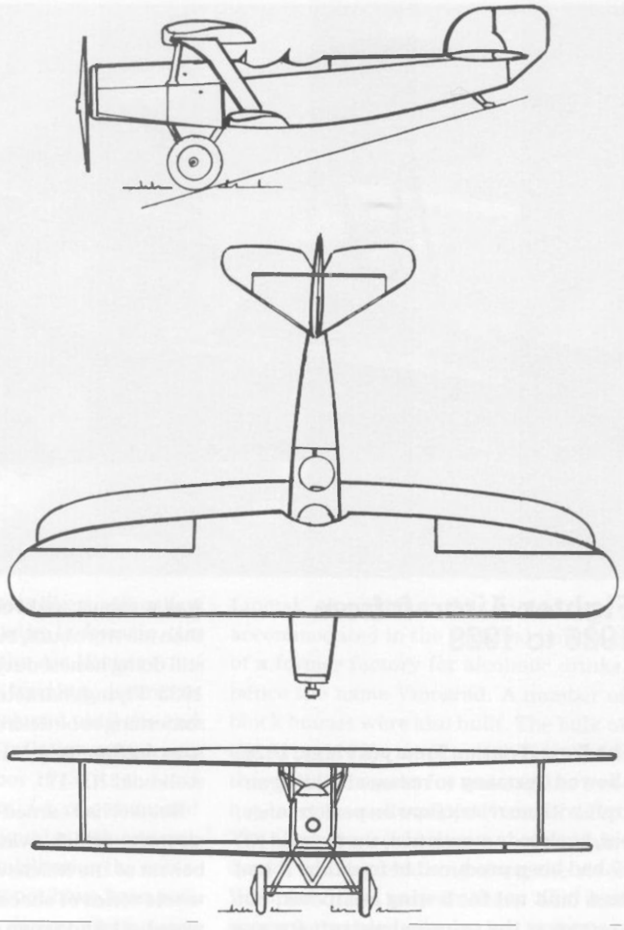
Fighter Aircraft from 1926 to 1929

The Paris Aviation Treaty (21 May, 1926) allowed Germany to resume building aircraft with no restrictions on performance, but, as already mentioned, the Heinkel HD 17 had been produced before this. It had been built not for testing at Lipetsk, but to serve as the principal aircraft for use there. Although not a combat aircraft in the true sense, the HD 17 earns a mention here because it was the basic mount of all fighter-pilot trainees at Lipetsk and played its part in many fighter aircraft developments there.

It was an unbraced biplane, very similar in structural terms to the Fokker D VII, and was powered by the 450 hp Napier Lion. The wooden wings had two spars with plywood skinning on the top surface back to the front spar, and back to the rear spar on the underside. The ply skin decreased in chord and thickness towards the tip. As on the Fokker D VII, N-shaped interplane struts were fitted to absorb the torsion forces. A version built by Svenska Aero had I-struts, which tended to obstruct the pilot's view. It is likely that this form of strut was turned down by the German authorities for this reason. The fuselage was a steel-tube structure with diagonal wire bracing. The front section was clad with sheet aluminium, the remainder covered with fabric. The undercarriage was very similar to that of the Fokker D.XIII, with a straight, one-piece axle sprung with rubber cord. Ailerons were fitted in the top wing only. The HD 17 was a robust and reliable machine; less than ten were built, but some of them were still doing honest duty eight years later, in 1933. Flying characteristics probably left something to be desired; one pilot assessed it as 'rather large and clumsy' and 'the stolid old HD 17'.

Heinkel had earned the right to build this aircraft, which was developed at the behest of the Reichswehr, by designing a whole series of successful aircraft which were built and flown abroad. Heinkel was a small company established immediately after the ban on aircraft construction had been lifted in May 1922. It specialised in developing prototype aircraft for all manner of customers. Production contracts which would have earned the company some real money could not be obtained. Heinkel's clients were countries which wanted a short-cut to modern technology, and required designs of sample aircraft which could be copied, or with which they could gain experience. Incidentally, the HD 17 was subjected to exhaustive testing at McCook Field, in Ohio, exactly like the Dornier Falke had been.

Heinkel's enterprises were marked by engineering skill and a keen business sense. The firm eventually developed a standard Heinkel constructional plan for biplanes, which in the next few years was applied to more than a dozen aircraft. By scaling the standard design up or down Heinkel could react like lightening to a customer's wishes and circumstances, without running the risk of introducing structural or aerodynamic difficulties. For example, the Design Office Manual included the measurements and profiles for the wingtip needed only to multiply



Heinkel HD 17 two-seat combat aircraft

Schütte Lanz D I
Wingspan 7.5 m, length 5.4 m.

these dimensions by the appropriate factor (which differed from type to type), to enable him to draw up spar and rib contours in a few hours ready for the workshop.

But back to the HD 17. Heinkel claimed that the government representative, Captain Student, whom we have met several times before, expected that Heinkel would take on the task even if the Reichswehr, (or the Reichs traffic ministry, or whatever name it was using at the time) could not give him a financial guarantee. 'It's no good hoping for riches from that man Student. Heinkel will have to look after its own financing. But he also made it clear that we were under a degree of obligation.' (Heinkel)

The means which the Reich could spare for military aviation were pathetically small. They had to be found from very limited funds, which were not public. Nevertheless it was a strange situation. Here was a representative of the Reich appealing to the generosity of an industry which was struggling for its very existence, and which had to scratch together its day-to-day funding by whatever means it could.

Between 1922 and 1933 German aircraft companies and foreign companies with German connections produced sixteen single-seat fighters and six two-seaters. The two-seaters could be classed as two-seat combat machines. Of this total of twenty-two, fifteen were built under contract to the Reichswehr. Only twelve of them were tested at Lipetsk, all of them biplanes, since that was what the military demanded. Four of the six single-seat fighters developed independently of the Reichswehr were not biplanes. Three were high-wing monoplanes in which the pilot

sat behind and slightly below the wing: the Junkers H 22 and the Dornier Falke, both dating from 1922, and the Rohrbach Rofix fighter designed in 1926. Somewhat later Junkers produced a further low-wing two-seater: the K 47. But the military totally ignored all four types, which is somewhat surprising in view of the fact that it was the Fokker D VIII — a cantilever high-winger — which had scooped the pool in the final fighter test series in 1918. It is almost impossible to imagine why the official preference for the one configuration was so strong, but it is perhaps indicative of how powerful the tides of taste and fashion can be. This is as good a place as any to explain what I mean.

Digression on the biplane

Germany's first fighter aircraft, built early in the summer of 1915, were the Fokker Eindeckers E I to E III, fitted with Oberursel rotary engines. The development and career of these machines are described in detail in the first part of this book. At the same time — the summer of 1915 — the firm of Schütte-Lanz offered the Flying Corps a small, lightweight biplane, also with the Oberursel engine, which the authorities declined. The reason: it was a biplane. But the designer can describe his experience himself[8]:

'These aircraft (the Fokker Eindecker E I — E III) were clearly not ideal for military purposes so the author decided to build a type, with one thing only in mind: it should be as small and light as possible! It was the first single-seat biplane fighter in Germany. When the designer demonstrated it to the army authorities, he received the memorable response that biplanes were completely useless as single-seat fighters because of their inherent obstructions to the pilot's vision. Six weeks later Fokker, who had studied the Schütte-Lanz aircraft in detail, managed to convince the powers that be of the practicality of the configuration, using a copy of my design to do so.'

Not long after, in 1916, the fighter aircraft was a biplane, and could be nothing other than a biplane. Albatros and Fokker and Pfalz and Roland and all the other companies built them exclusively, until the Air Corps, the Idflieg and the aviation industry succumbed to triplane fever. As described earlier, the triplanes were 'passé' again by the end of 1917. The single-seat biplane fighter came back into favour for a year until the cantilever monoplane arrived at the end of 1918.

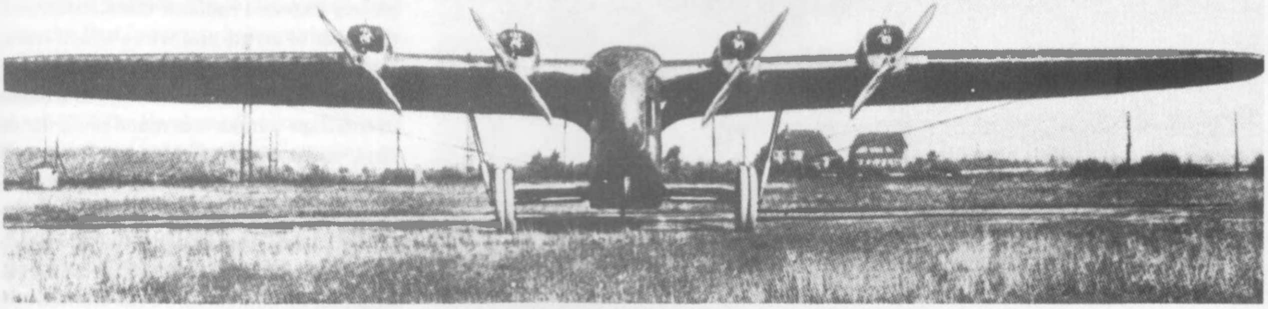
When the Reichswehr decided to equip its armed forces with single-seat fighters, it only really considered the biplane. This biplane fixation was to remain until 1933. Nothing better had come up, and if it had, it was not to be trusted. Other countries were influential in this respect, especially Britain. One example is wing loading. 13 lb/sq ft was a sacred figure for a long time. This is about 65 kg/sq m. (Later designers dared to go up to 15 lb/sq ft, around 75 kg/sq m.) Landing speeds at such wing loadings were 115 to 125 km/h, and these figures were quite high enough considering the quality of the airfields which were available. High-lift aids and landing flaps had not been invented, or were only just on the horizon. Nobody dared think of sprung, properly damped undercarriage struts, oil-filled shock absorbers and the like. It all looked too complex, not primitive enough, and flying machines were meant to be primitive. A monoplane built within the wing loadings which were considered permissible called for an increase in wingspan of 12 to 15 per cent, the result of which was a low roll rate, and this was precisely what was not required.

For many reasons it was thought advisable to keep to the proven method of wing construction using wood and fabric, and with this restriction the braced biplane was lighter and stiffer, offered better stability and climb performance, and had superior aileron response and rate of roll.

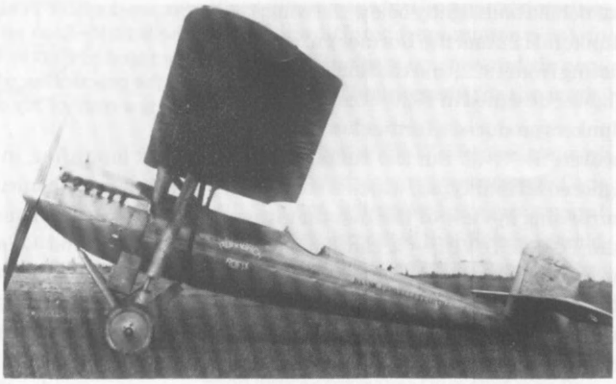
The drag of the six struts and four wires of a biplane with bracing in a single plane is small in comparison with that produced by the standard undercarriages, which had at least six struts plus wheels and suspension. To put it crudely, if the retractable undercarriage was excluded as a possibility, then the braced biplane was a good compromise within the existing or self-imposed restrictions. By the latter we mean such ideas as 'the aircraft should look or be primitive', or 'we cannot burden the pilot with the complication of a landing aid just at the moment when he is concentrating on the landing', or 'he may forget to retract the landing aid and overload the aircraft', or 'very many pilots would forget to extend a retractable undercarriage before landing, and the extent of accidental damage would be greater'. All these arguments can be summed up as follows: 'we've always done it like this' or 'we've never done it like that'.

The Rohrbach Rofix Monoplane

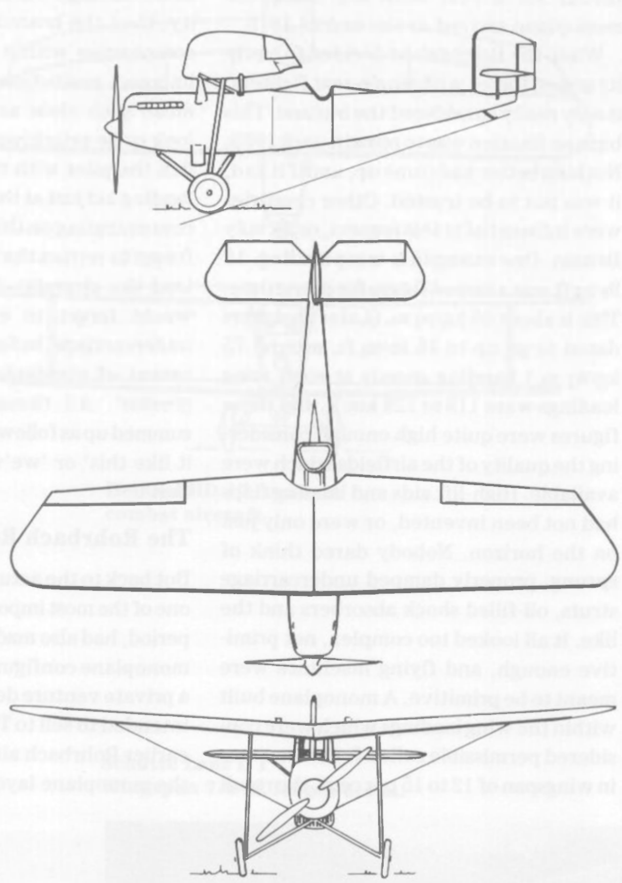
But back to the actual aircraft. Rohrbach, one of the most important designers of that period, had also made the transition to the monoplane configuration with the Rofix, a private venture development, which he intended to sell to Turkey. If we consider earlier Rohrbach aircraft the adaption of the monoplane layout is easy to explain.



The E.4/20 of 1919-20. Designed by Adolf Rohrbach and built at Staaken: wingspan 31.0 m, length 16.6 m, wing area 106 sq m, all-up weight 8,500 kg, four 260 hp Maybach engines.



The Rohrbach Ro IX Rofix all-metal single-seat fighter.



Ro IX Rofix

Wingspan	14.0 m
Length	9.5 m
Wing area	28 sq m
All-up weight	1,950 kg
BMW VI U	550/680 hp

In 1918-19 he had built the first large four-engined monoplane, the Staakener Eindecker, which was something completely new.

The Ro IX Rofix was described in the company as a single-seat combat aircraft, and its wings and fuselage were made largely of duralumin. The two-part wing tapered straight from the centre, and was braced to the fuselage by a single cable on each side. The central part of the wing formed a parallel-sided box structure, to which the front and rear sections were attached in the form of 'leading and trailing rib boxes'. The thick outer skin of the central part was stiffened with profiled dural strips, and was stressed to absorb tensile and compressive loads. The leading and trailing rib boxes were skinned with thin sheet duralumin. The fuselage had an elliptical cross section. Open profiles were used exclusively, as they could be riveted and maintained easily. The outer skin consisted of thin sheet aluminium, which was part of the load-bearing structure. This description has been taken almost word for word from the original works description of this structurally very advanced aircraft, whose wings incorporated a method of construction which was unique to Rohrbach.

In many respects the gains expected from the monoplane layout were not realised. Obvious drawbacks were the completely exposed radiator installation and the mass of struts and wires which hung out in the airstream. This is particularly evident in a front view. The dihedral angle of this high-winger was much too great at first, and it was probably altered several times. Some pictures show very pronounced dihedral, others a perfectly straight wing, and a flight report written by Udet mentioned dihedral of $-1\frac{1}{2}$ degrees, *i.e.* anhedral. To the trained eye the fin looks too small, and Udet also picked that up in his flight report. It is likely that this was the cause of the aircraft

crashing after a spin. This incident ruffled many feathers. Rohrbach was charged in court with negligence in the construction of an aircraft. He was asked why he had built a fighter aircraft capable of aerobatics in the form of a monoplane. 'Such an aircraft may only be a biplane'. Naturally the Rofix accident was grist to the mill of the biplane proponents.

Planning and Development from 1926 to 1929

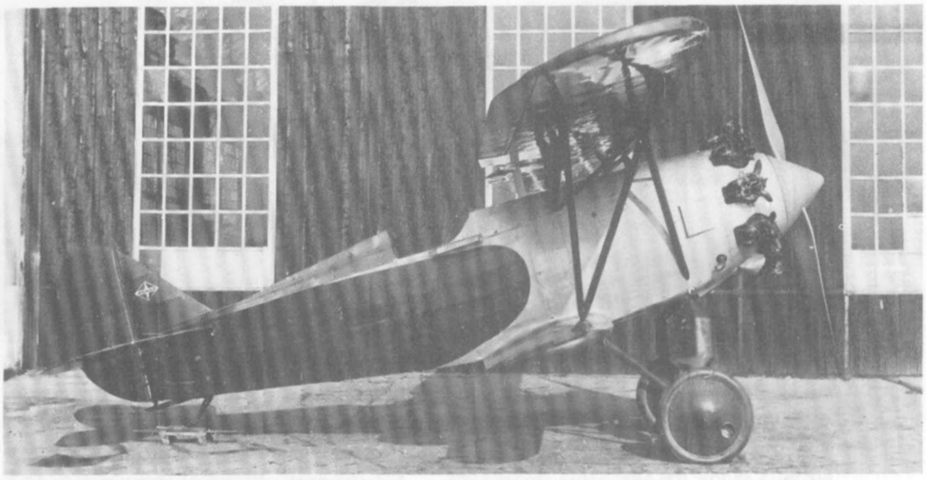
With the signing of the Paris Aviation Treaty on 21 May, 1926, serious planning for an air force seems to have begun. Under the terms of the treaty the restrictions were lifted, allowing construction of aircraft with acceptable performance for military purposes. The technical developments sectiion (aircraft) in the army weapons office, under the direction of Captain Student, had laid down requirements for the development of a series of four types, each with a code name. These were: a single-seat home fighter (code name Heitag), a reconnaissance aircraft for divisional reconnaissance squadrons (code name Erkudista), a night fighter and reconnaissance aircraft (code name Najaku) and a long-range, medium-altitude reconnaissance aircraft which could double as a medium bomber (code name Erkunigros). For the Heitag project, probably Heimat Tagjäger (home day fighter), the firm of Arado in Warnemünde produced the SD I fighter. The origins of this firm are somewhat misty, as is so much from this period.

The Werft Warnemünde des Flugzeugbaues Friedrichshafen GmbH (Warnemünde yard for Aircraft Construction Friedrichshafen Ltd) founded in the year 1917, was taken over in 1921 by the Stinnes concern. It is said that Hugo Stinnes' plan was to set up aircraft factories throughout the world to manufacture and distribute German aircraft in a co-ordinated manner. The Warnemünde yard was the first factory to be acquired as part of this plan, but the plans were abandoned when Hugo Stinnes died in April 1924. In April 1925 the Hamburg division of Stinnes formed the Arado Trading Company, to which the Warnemunde yard belonged. Under the name Werft Warnemünde der Arado Handels GmbH (Arado Trading Company, Warnemünde yard) the factory continued in existence. The managing director was Lieutenant-Colonel Wagenführ (retired), who had held an influential post on the technical side of the aerial armed forces before and during the war. According to the original Stinnes plan the Warnemunde yard was to be purely a manufacturing operation, while the designs were to come from other sources, *e.g.* Heinkel. Of the HD 21 and HD 32 training aircraft Arado built fifteen and four units respectively. As further production contracts were not in the offing, the directors of the business had to try to undertake their own development work. Walter Rethel, a great-nephew of the famous painter and graphic artist Alfred Rethel, took over the design office. He had been active in the Kondor works at Essen during the war, and had joined Fokker in the Netherlands in 1918.

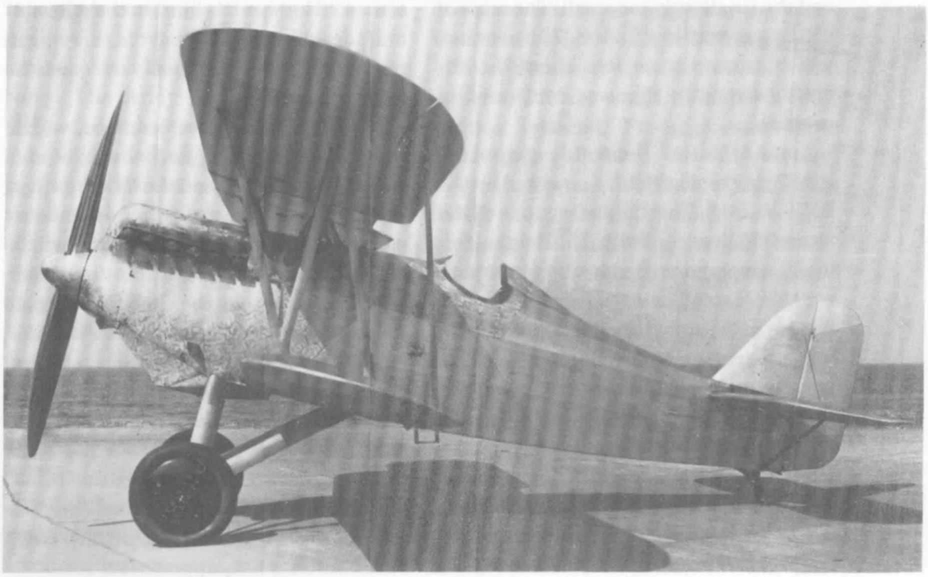
It may be that Rethel's experience with Fokker made the difference, or perhaps it was the solid reputation of a number of training aircraft which were built under his direction, but in any case the Reichswehr's first fighter aircraft contract went to the firm of Arado. The aircraft followed very closely the style of Fokker aircraft of the previous war, or the Fokker D.XIII. the fuselage was based on a steel-tubing skeleton, skinned with sheet aluminium at the front, and fabric at the rear.

The cantilever wings were made of wood, and the conventional spar-rib structure was covered with plywood as far as possible. A single V-strut on either side between the much smaller lower wing and the upper wing was intended to reduce torsional effects, as on the Fokker D.XIII. The wing attachment was just like that used on the Fokker D VII on many subsequent steel-tubing fuselages. The power plant was the nine-cylinder Gnome-Rhone Jupiter of 425 hp. It had been developed by the British firm of Bristol, and Gnome-Rhone acquired a licence to build it.

One innovation compared with older

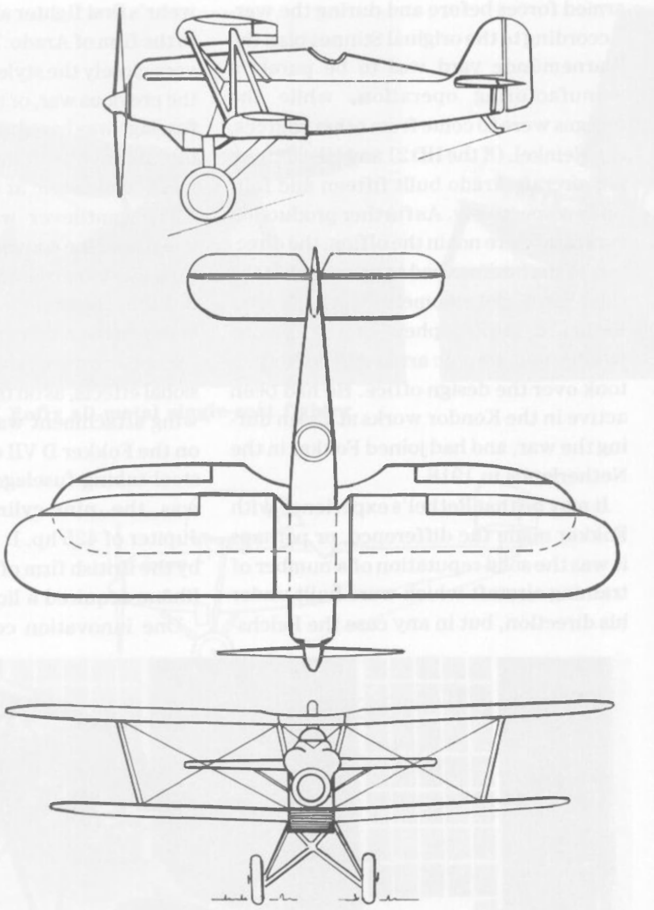


The first Arado fighter - the SD I.



Heinkel HD 37.

Heinkel HD 37



fighters was the undercarriage, whose front legs took the form of spring struts. The suspension was based on V-shaped rubber cords, which provided some progressive springing effect as the angle of the V altered under compression. All in all the aircraft made an agreeable impression, although the tail was somewhat too short and the fin slightly too small. The mass of 850 kg was very low for the 425 hp engine, which arouses suspicions about the aircraft's strength; this was confirmed in practice.

Around this time Heinkel developed the HD 37 single-seat fighter powered by the BMW VI 7.3 Z. This fighter was one of the aircraft built according to the Heinkel formula: a biplane braced in one plane with a single N-strut on each side. The lower wing was considerably smaller, and both wings were fitted with ailerons, interconnected by a pushrod located behind the pivot point.

If we compare the empty mass of the HD 37 – stated as 1,267 kg – with the corresponding figure of 1,490 kg for the Arado 65, which was developed three years later but was equipped with the same engine, then the only possible conclusion is that the HD 37 must have been seriously weak in some areas, unless we accept that 223 kg of superfluous weight was built into the Ar 65. The Ar 65 was the final result of a period of development extending as far as 1933, and it met all the requirements for strength, flying characteristics and operational reliability. The extra mass of some 220 kg was the burden that the aircraft designer could not avoid carrying if the aircraft was to be really adequate in every respect.

The HD 37's high performance, which was a direct result of its low weight and small size, so impressed the Russians that they obtained the rights to build it, in spite of its temperamental flying qualities which were a consequence of its short fuselage.

It is possible that the German authorities were not completely satisfied with the aircraft, as only two were built. It is also possible that they were only experimental machines, built to establish that the basic structural design was a practical proposition, for the Arado SD II and SD III also appeared around this time.

These two shared a common airframe, and both were equipped with Siemens Jupiter engines. However, one of them had the geared version, the other the normal, non-geared unit. In the meantime Siemens had obtained the Jupiter licence from Gnome-Rhone, which the company had obtained from Bristol.

The large, slow running propeller of the geared engine demanded a tall undercarriage, with the result that the angle of attack on the ground was unusually high. This feature, together with the powerful torque of the propeller resulted in unpleasant take-off and landing qualities. The aircraft tended to ground-loop on take-off and landing unless the pilot exercised extreme care. Like its predecessor, the SD I, the machine had a wooden wing, with fuselage and tail surfaces of steel-tube. The difference in this case was that the biplane was braced, instead of cantilever. The lower wing was considerably larger than that of the SD I, although still smaller than the upper wing, and ailerons were fitted to the upper wing only. The wingspan, at 9.9 m, was almost 20 per cent greater than that of the SD I, and the empty weight had increased by almost 70 per cent. Bearing in mind what was said earlier about increases in size, this was further evidence that the SD I had serious structural weaknesses.

The Arado SSD I

In the first few years after the lifting of the restrictions the German aviation companies turned out to be as prolific as in the previous war. For the first time they had the chance to serve two masters, as the Navy now wanted to be supplied with aircraft to its own naval requirements. For a long time Heinkel and Arado fed from two bowls — Army and Navy. Viewed from a different angle, this meant that the extremely scant financial means available for development work were divided up for parallel developments running simultaneously. In this account of the development of fighter aircraft we have deliberately omitted the naval fighter: on the one hand their influence on overall development was extraordinarily slight, on the other the task of the naval fighter could have been done better by a land-based aircraft in almost every single case. The best evidence for this assertion is the fact that the naval fighter aircraft, and indeed seaplanes in general, died out. The Arado SSD I nevertheless deserves a mention here, as it was fitted with a wheeled undercarriage for testing at Lipetsk, and thus could also claim to be a land-based machine. The aircraft was also used for

Arado SD II

Wingspan	9.9 m
Length	7.4 m
Wing area	23 sq m
All-up weight	1,770 kg
Siemens Jupiter	530 hp

SD III

Length	7.75 m
Siemens Jupiter	490 hp

Arado SSD I (land)

Wingspan	10.0 m
Length	8.5 m
Wing area	31.0 sq m
BMW VI	650 hp

experimental work on setting the upper wing below the pilot's eye level. Similar tests had been made many times in the First World War.

The depth of the fuselage dictated by the engine or the pilot is usually less than the theoretically ideal distance between the wings. If the fuselage is raised until its top surface meets the upper wing, the resultant gap between the upper surface of the lower wing and the fuselage is extremely disturbing in aerodynamic terms, *e.g.* Pfalz D XV or Albatros Dr I, unless you wish to build an extremely deep fuselage, such as on the LFG Roland Walfisch (Whale). On the Arado SSD I this gap was filled very elegantly with a cowled radiator. This 'channel radiator' installation was aerodynamically much better than what was used over the next five or six years. In fact, the radiator installation remained the bugbear of aerodynamics for many a long year.

In its naval form, with one central and two auxiliary floats and more than two dozen struts, the Arado SSD I was nothing like as good a machine as the land-based version even with its temporary undercarriage. The machine was a single-bay plane with N-form interplane struts, braced in one plane, and equal-sized upper and lower wings, both fitted with ailerons. It would certainly have been worth developing further, but it had been built under contract to, or at the desire of, the Navy. The Army had its own projects under development. There was as yet no independent flying corps. During this period the General Staff considered the aerial armed forces as a form of Army — or Navy — weapon, which supported the operations of the organisations to which they belonged.

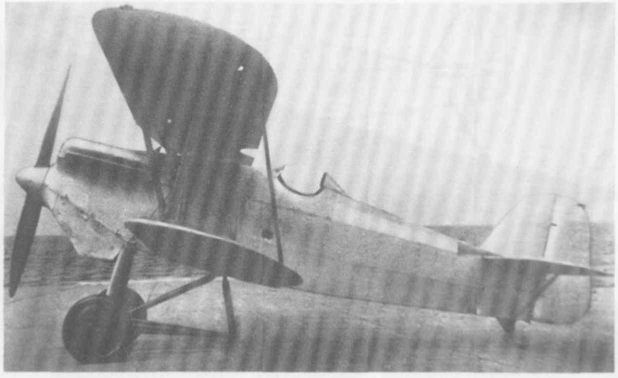
As well as the central float Arado SSD I fighter, the Navy was also promoting a Heinkel fighter with twin floats. This was the HD 38, also powered by the BMW VI. Evidently the Army favoured the air-cooled radial engine at this time, while the Navy preferred the water-cooled inline layout for its fighter aircraft. The HD 38 was designed for interchangeable float and land undercarriage right from the outset. It was flown as a land-based aircraft at first, in which guise it was tested at Lipetsk before being fitted with floats.

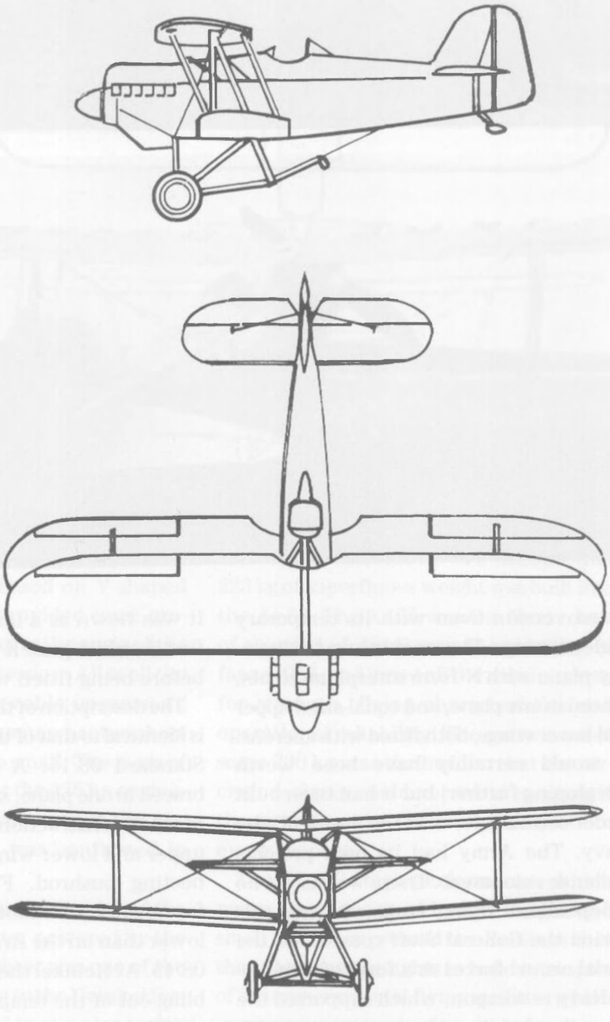
The description of the HD 38 Land design is identical to that of the Arado SSD I Land, Standard 08/15. A single-bay biplane, braced in one plane, single N-struts, wings of wood construction with ailerons in the upper and lower wings, linked by a connecting pushrod. Fuselage: steel-tube framework with fabric covering, but set lower than on the Arado SSD I, Standard 08/15. At Heinkel the biplanes were tumbling out of the template store. Even so, the HD 38 was a thoroughly competent aircraft for its time. The weaponry, which was never installed until the machines reached Lipetsk, consisted of the usual two 7.9 mm 08/15 machine-guns, as on all other German aircraft.

The Two-seat Combat Aircraft

It appears that Albatros, famous in the war for its single-seat fighters, devoted itself entirely to the development of two-seaters for the Army's air force, and these

Heinkel HD 38.





Heinkel HD 38

Wingspan	10.0 m
Length	7.7 m
Wing area	30.4 sq m
Airframe weight	1,532 kg
All-up weight	1,858 kg
BMW VI	550/730 hp

machines were, of course, biplanes. (No case is known of the Reichswehr awarding a contract for a monoplane combat aircraft before 1933.) Albatros seems to have had no competition in this area. The development of the combat two-seater can probably be traced back to the initiative of Walter Blume, a First World War Pour-le-Mérite fighter pilot with 26 kills to his credit. Blume, who had helped to build the Vampyr glider during his period of study in Hanover, was a director of Albatros. His experience in aircraft with no rear defence caused him to return again and again to this problem. Even in his later post as technical director of the Arado aircraft works — Albatros had gone bankrupt in 1932 in the general economic crisis — Blume continually directed his attention to the development of rearward and all-round armament.

The first combat two-seater to be built was the Albatros L 76 Aeolus. This was a biplane with unequal wings, BMW VI engine, unbraced two-spar wings with N-type interplane struts, skinned in plywood as far back as the rear spar. As was the fashion of the day, the fuselage was built as a steel-tube framework with fabric covering. The undercarriage had a straight full-length axle. The rear legs of the V-struts were sprung, which gave the machine a disquieting tendency to alter heading if one wheel touched down first. As on almost all aircraft of the time the fin was too small, and the aircraft had a tendency to fall into a spin unexpectedly, and was difficult or even impossible to recover; the result was two fatal crashes. The fin was considerably increased in size after this, and the tail end of the fuselage was also made deeper. This is reminiscent of the changes made to the tail end of the Fokker D VIII in comparison with the Fokker Dr I and D VIII. The altered L 76 was designated the L 77, but the two designs were identical apart from the changes to the rear of the fuselage and tail surfaces and a few detail alterations. It had the same undercarriage and the same crude radiator installation. The aircraft was exploited to the full for the purpose of weapons testing at Lipetsk. The armament of all these aircraft consisted, as ever, of the two fixed forward-firing 7.9 mm machine-guns and one rear free-mounted gun, as in 1917. Evidently tests were made at Lipetsk on a rear free-mounted 20 mm cannon.

The company's next combat two-seater, the Albatros L 78, was also fitted with the

Albatros L 76 with machine-gun on rotary mounting, on test at Lipetsk.

Albatros L 77, with modified tail surfaces.

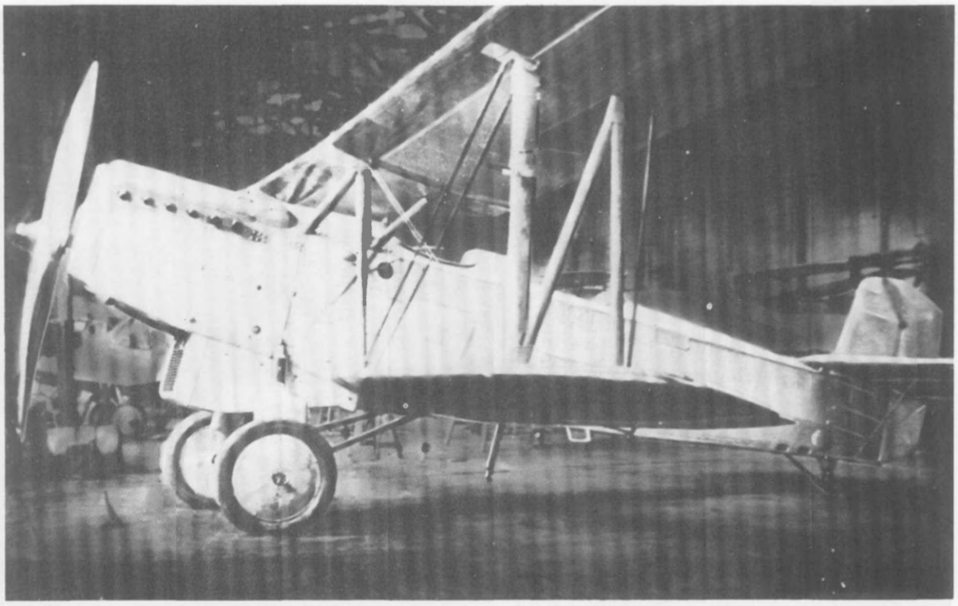
600 hp BMW VI, and represented Albatros' return to the braced biplane. The strong strut which ran from the bottom edge of the fuselage to the cabane, and formed the main connection between fuselage and wing in conjunction with the N cabane struts, was now located towards the leading edge. Twin diagonal bracing wires of aerofoil section ran from the upper spar to the lower wing root at the front spar. Ailerons were fitted to the upper and lower wings. They were linked by a connecting rod attached behind the aileron hinge axis, which does not look very promising with regard to wing flutter and aileron vibration; these effects duly set in when the machine was suitably provoked. The tail end of the fuselage was even deeper than that of the preceding L 77. In this case it was the forward undercarriage legs which were sprung; the result was an unwanted change in tracking angle if the load on the wheels was asymmetrical. The radiator installation looked even more awkward than on the preceding types. But all in all the aircraft seems to have been reasonably satisfactory, and quite a number of them were built. This was, however, the end of the line of development. Certainly the Reichswehr seems to have invested no further money in the two-seat combat aircraft.

The Junkers K 47

There was one other two-seat, low-wing combat aircraft: the K 47, from Junkers. Like all Junkers aircraft up to 1934, it was developed entirely independently. The machine deserves mention here for a number of reasons. The designation K 47 in fact covers several variants of the structure. Initially it was a mid-wing monoplane, braced in one plane, and built completely in flat sheet metal. The underside of the wing was braced to the undercarriage by a pair of profiled wires, while on the top surface a single wire ran to a small spine on the top of the fuselage. The spine allowed the top bracing wires to be set at a favourable angle, and also served to protect the occupants if the machine turned over. The wing was of constant chord for 50 per cent of the semi-span, and tapered gently outwards from that point; a good planform from the point of view of stalling behaviour.

The wing of the second test aircraft was made largely with corrugated sheet metal in place of wing ribs, at the wish of Hugo Junkers, although the leading edge was

Albatros L 78.



Junkers K47. First braced version, entire aircraft covered by flat sheet metal.

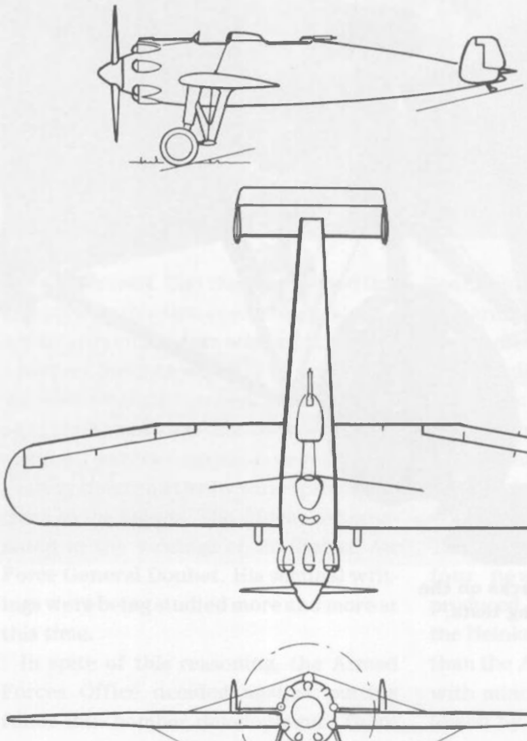
still covered in flat sheet. The bracing wires were replaced by a strut from the wing to the undercarriage. The wing had three spars with strong lateral members at the points where forces were concentrated. The tail surfaces were also made of corrugated sheet, but the fuselage retained flat sheet metal skinning, with L-section stringers running through notches in the formers. This was the first flat sheet monocoque fuselage of its kind, and pointed the way for the future. There were twin fins, mounted at the tailplane tips. This arrangement provided the widest possible firing arc for the rear gunner, and it was an arrangement often adopted in later designs. In this case it offered an additional advantage: it eliminated the disturbing influence of the propeller airflow on directional stability.

The original design of this two-seater was the work of Karl Plauth, a First World War combat pilot, who knew only too well the Achilles' heel of the single-seat fighter. He had studied at Darmstadt after the war, had been one of the co-founders of the Darmstadt Akademische Fliegergruppe in which he had designed a light aircraft, then went to Junkers where he was greatly appreciated by Hugo Junkers. Junkers gave the go-ahead for the development of the K 47 project on 2 November, 1927, but on the following day Plauth was killed in a crash after a wing broke during an outside loop.

The design work was then continued by Herrmann Pohlmann at Dessau, where the aircraft's components were built for assembly in Limhamm, a suburb of Malmö, by the Swedish firm of A.B. Flygindustri. A number of K 47 aircraft were also built for the Swedish Air Force and for export to China. The total built was about 25 units.

The K 47 was tested thoroughly at Lipetsk, where it became very popular among the pilots. A report from Lipetsk expressed the desire for more of them. However, the independent Junkers projects were not made to measure for the

Junkers K 47, modified braced version, wing in corrugated sheet metal, except for leading edge.



Technical Requirements which had been laid down by the Reichswehr. For this reason, and also because it looked to be more expensive than wood/steel-tube designs, this highly promising concept was not included in the procurement plan which had been drawn up against the time when an air force would be established.

The Reichswehr's preference for the wood/steel-tube/fabric construction method cannot be denied a certain justification. The manufacture of aircraft of this type can be improvised much more easily. Individual components can be manufactured in small and even tiny factories, or even at home. And that was probably the plan. Even the smallest part had its own special, dimensioned drawing, and was identified by a code number alone. The intention was that these parts would be contracted out to the small concerns mentioned above, so that preparations for building the aircraft could be carried out in complete secrecy.

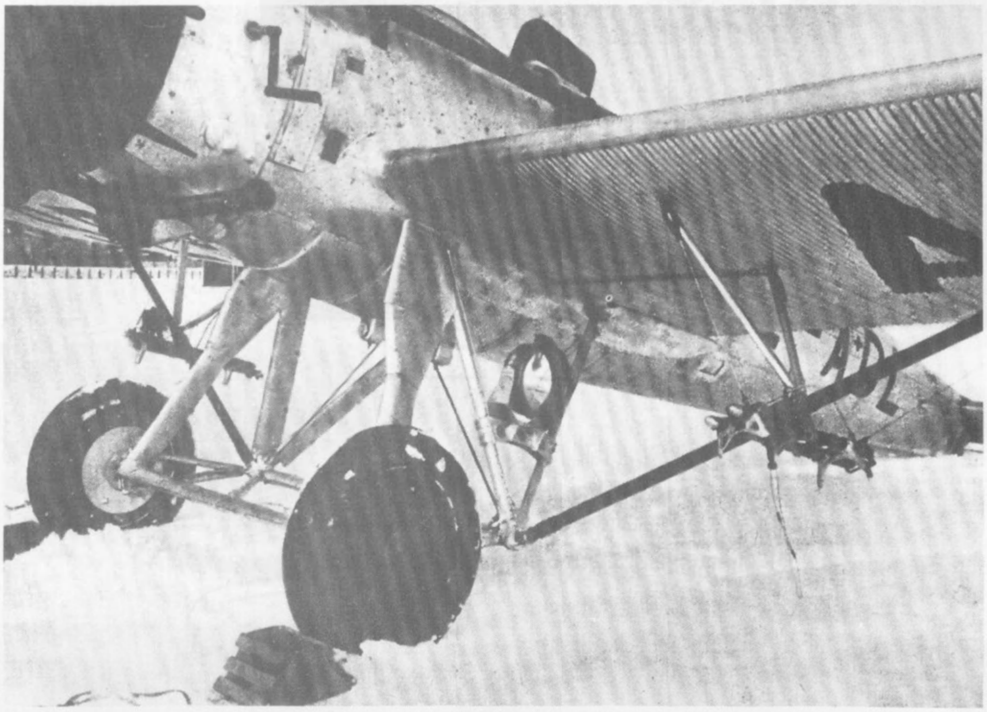
The parent organisation was a company known as Fertigungs GmbH (Manufacture Ltd), which was responsible for monitoring technical matters, component strength, quality control, etc. for all aircraft planned for the Reichswehr. The company had been specially set up in parallel with the authority responsible for civil aircraft, in order to keep the number of people aware of the project, and taking part in it, as small as possible.

Years later, as part of the preparation for

Junkers K 47

Wingspan	12.4 m
Length	8.55 m
Wing area	22.8 sq m
Empty weight	1,050 kg
All-up weight	1,650 kg
Bristol Jupiter	550 hp

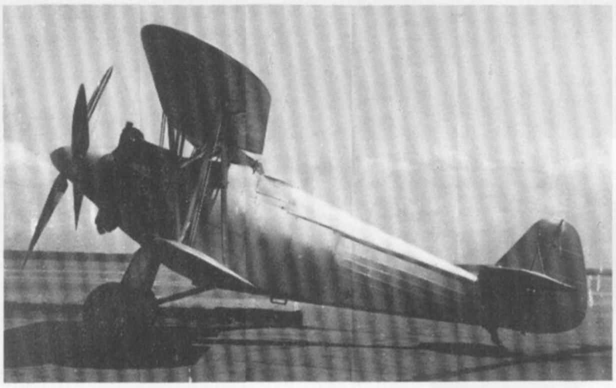
a dive-bomber project, the all-metal K 47 aircraft were taken to Sweden, where they were fitted with dive-brakes, dive sights (Stuvi) and an automatic pull-out mechanism coupled with the bomb release, in co-operation with the firms of Bofors and Anschütz. In this form the aircraft's bomb racks were fitted to the wing strut support point, outside the propeller disc. This was the basis for the later (1934) Ju 87 dive bomber (Stuka), which was also designed by Herrmann Pohlmann. The lines of aircraft development are often linked in this way.



Junkers K 47, with bomb racks on the wing struts for dive-bombing tests.

The Period of Re-armament, 1929-1932

The German Aviation Boom



Arado Ar 64. Geared Siemens Jupiter of 490 hp. Virtually identical to the Arado SD III.

Now we return to the period 1928-29. Germany's economy had recovered substantially. Civil aviation in general was making great progress. At the end of 1929 Germany held no less than 12 of the 35 records for land-based aircraft recognised by the FAI (Fédération Aéronautique Internationale), *i.e.* more than one third of them. The corresponding figure for seaplanes was more than half. They were almost entirely records of altitude, duration and range with payloads of several tons, *i.e.* records for passenger and freight aircraft, and they were set up by that sort of machine.

Promotion of this class of aircraft was funded out of the budget of the Reichsverkehrsministerium (Reich Transport Ministry), and the considerable number of international best performances is ample evidence of the success of these efforts on the part of the RVM. The director of the aviation department, Minister Brandenburg, had been a Pour-le-Mérite pilot in the First World War, was acquainted with the requirements of military aviation, and kept them in mind during his period at the RVM. After all, virtually all the knowledge and experience obtained in the building and operation of civil aircraft could be applied equally to military aircraft, and vice versa.

Unfortunately the German economic recovery was short-lived. The world economic crisis, which began with the great New York stock market crash on 24 October, 1929, paralysed German economic life, and the funds available for aeronautical research and development shrank again, although the budget which the Reichs Government granted to aviation was amazingly high considering the overall situation. Even so, the second four year programme in the German aeronautical development plan, from 1929 to 1932, was necessarily much smaller in extent compared with the first four years from 1925 to 1929.

This programme was intended to include bomber aircraft. The thinking behind this was presumably that even though waging a war without fighters was bound to lead to defeat, neither would it be possible to win a war without bombers. A further consideration was that the most effective means of defence against bomber was to destroy them and the factories producing them on the ground. These ideas had originated in the writings of the Italian Air Force General Douhet. His seminal writings were being studied more and more at this time.

In spite of this reasoning, the Armed Forces Office decided against putting funds into bomber development. There were many reasons for this decision. The development of a four-engined bomber would consume the major part of the money which was available in the limited, non-public funds: at least four times as much as the development of a single-seat fighter with the same engine. If Douhet's strategic thinking was correct, the number of bombers required to wage war successfully was far beyond what Germany could afford at that time. Moreover the development of bombers was more likely to be perceived as an intent to attack, even if the aircraft were intended for a defensive strategy — *i.e.* for counter-attacking. There must have been some hard bargaining within the various aviation sections of the Reichswehr, since the requirements for the second armament period were not disclosed to the aircraft building industry until the end of 1929.

As far as the fighter is concerned, these requirements are easy to sum up. The Government wanted something better than before, but costing less.

If the decision had been reversed, the development of a bomber would inevitably have been extremely expensive. New engines had to be developed, and something had to be done about new equipment — bomb-aiming devices, radio and so on. Thus it was that up to the end of 1932 only four new single-seat fighters were produced. These were the Arado Ar 64 and the Heinkel HD 43, which were little more than the Arado SD III and Heinkel HD 38 with minor refinements. They were followed by the Arado Ar 65 and Heinkel HD 49, which appeared to be fundamentally new designs, but they were still wood, steel-tube and fabric aircraft, and still armed with two 7.9 mm MG 17 machine-guns. As a result of the experiments undertaken at Lipetsk these machines were equipped to carry five or six 10 kg bombs for infantry bombardment. In performance terms they differed little from their predecessors. What they had gained in higher level flying speed they had lost in climb performance, on account of their greater weight. Although the machines were now heavier, they were correspondingly stronger, better equipped (for the first time they had really effective wheel brakes, for example), easier to operate and maintain, and were far superior aircraft in their usefulness.

The Arado Ar 64 was a development of the Arado SD II, and indeed it was difficult to distinguish between the two, the

Heinkel HD 43

Wingspan	10.0m
Length	7.5 M
Wing area	26.7 sq m
Empty weight	1,210 kg
All-up weight	1,630 kg
BMW VI 7.3 Z	550/730 hp

Arado Ar 65.

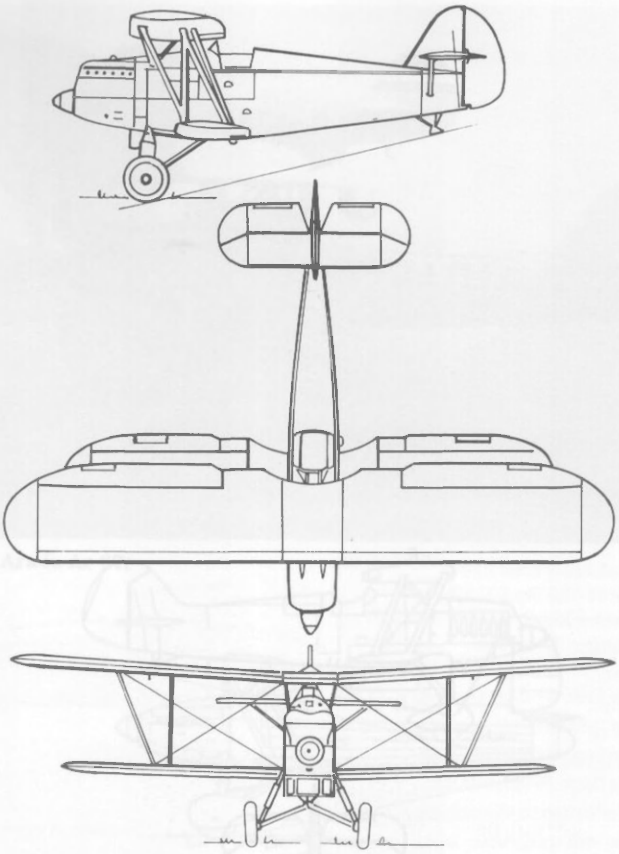
Arado Ar 65, the first machine produced for the new German Luftwaffe.

fuselage was somewhat longer, the fin and rudder were larger but with a slightly narrower fin, in an attempt to improve the rather difficult flying characteristics. But nothing was fundamentally new. Powered by the same geared Siemens Jupiter as was used in its predecessor, with its large, four-bladed propeller, the Ar 64 had the same unpleasant take-off and landing qualities. The next Arado fighter, the Ar 65, was fitted with the BMW VI, like the HD 43. It took a practised eye to differentiate between the two aircraft at first sight: both were staggered biplanes with slightly smaller lower wing, and a rectangular wing planform with rounded tips. Ailerons were fitted to both wings, and were linked by a connecting rod. The Ar 65 had been preceded by an experimental Ar 64 fitted with a BMW VI engine, which indicated that the fuselage should be 60 cm longer, deeper at the tail end, and have a larger fin. With these modifications the Ar 65 was an extraordinarily docile, easy to fly aircraft, whose flying qualities were a marked improvement on previous developments. To a large extent these improvements were due to the work of the test pilot von Schönebeck, a former World War fighter pilot, whom we have already met in conjunction with the Dornier Falke. Naturally, he was also a member of the Lipetsk team. In the early thirties he was director of the Rechlin test centre.

The Ar 65 was subsequently built in quite large numbers, as it was to form the cornerstone of the fighter section of the Luftwaffe, which was formed in 1933.

When the Ar 65 proved a success, work on the Heinkel HD 43 was discontinued. Heinkel's next design was the HD 49, which broke new ground for the company. Gone were the angular lines, the box fuselage cross-section; instead the fuselage was slender, elegant and rounded. The improvement was probably more visual than actual, for a braced biplane with fixed undercarriage, crude radiator installation and open cockpit offered such high drag that the resistance of the fuselage was relatively insignificant. Incidentally, the small improvement in drag resulting from the rounded fuselage was partly nullified by the transition between the lower wing and the round fuselage, which is a very difficult area in aerodynamic terms.

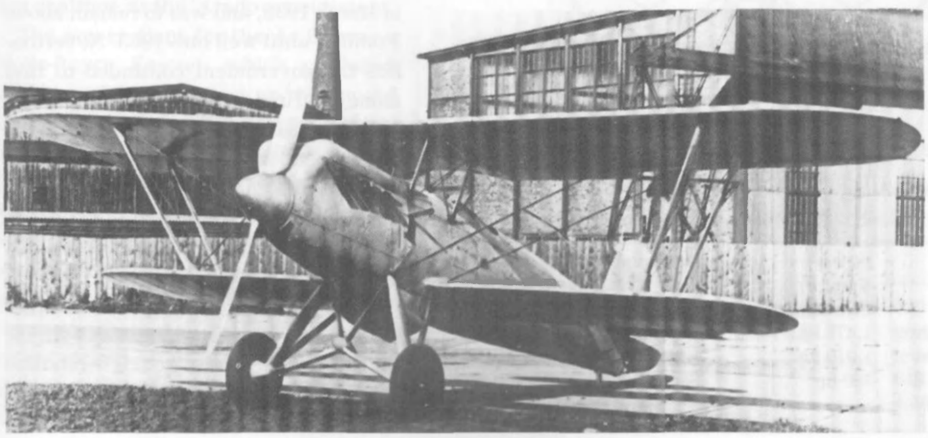
The HD 49 first flew in November 1932, but once again the expected improvement in performance did not materialise, and the aircraft was revised again. This time the standard undercarriage with its six struts and (divided) axle was replaced by



Arado AR 65

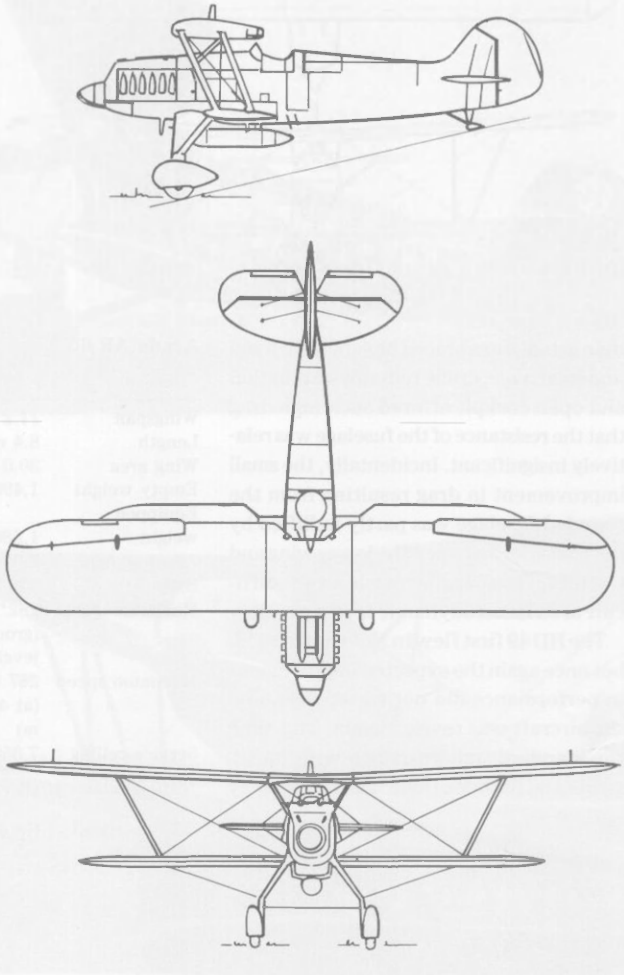
Wingspan	11.2 m
Length	8.4 m
Wing area	30.0 sq m
Empty weight	1,490 kg
Equipped weight	1,580 kg
All-up weight	1,865 kg
BMW VI 7.3 Z	750 hp
Maximum speed	282* km/h (ground level)
Maximum speed	267 km/h (at 4,000 m)
Service ceiling	7,350 m

*officially measured values



Heinkel He 49.

Heinkel He 51A, the successor to the Ar 65.



Heinkel He 51A

Wingspan	11.0 m	Maximum speed	315 km/h (ground level)
Length	8.4 m		
Wing area	27.2 sq m		
Empty weight	1,475 kg	Maximum speed	295 km/h (at 4,000 m)
All-up weight	1,910 kg		
BMW VI 7.3 Z	750 hp	Service ceiling	7,500 m

a single-leg undercarriage braced to the lower wing. The result was the He 51, whose first flight took place in the summer of 1933[9]. In other respects the two aircraft were almost identical. The He 51 was tried with a fairing behind the pilot's head; a feature which had been tried during the First World War. As in that case, it was a one-off fitting to the prototype, and was then abandoned. It was really just a styling improvement, and styling has no place on a military aircraft.

A few dozen He 51s were built initially, followed by a few hundred more once secrecy was no longer required. They were the successor to the Arado 65 as standard equipment for the fighter squadrons of the Luftwaffe. Quantity production had to wait until 1935-36, when larger factories had been built. At first the funds available were extraordinarily limited. When studying and assessing the whole of this second period of armament (1929-32), we have to bear in mind that it took place against the background of a difficult economic situation. Unemployment in Germany was growing, reaching a climax of 6.1 million in March 1932, and was to remain above 5 million until well into 1933. Nevertheless the government continued to find money to fund development of military aircraft. Albatros had gone bankrupt in the general economic ruin, and Walter Blume had moved to Arado to take up the post of technical director there. In 1932 Arado produced the AR 67 and AR 68 designs, both of them biplanes, naturally.

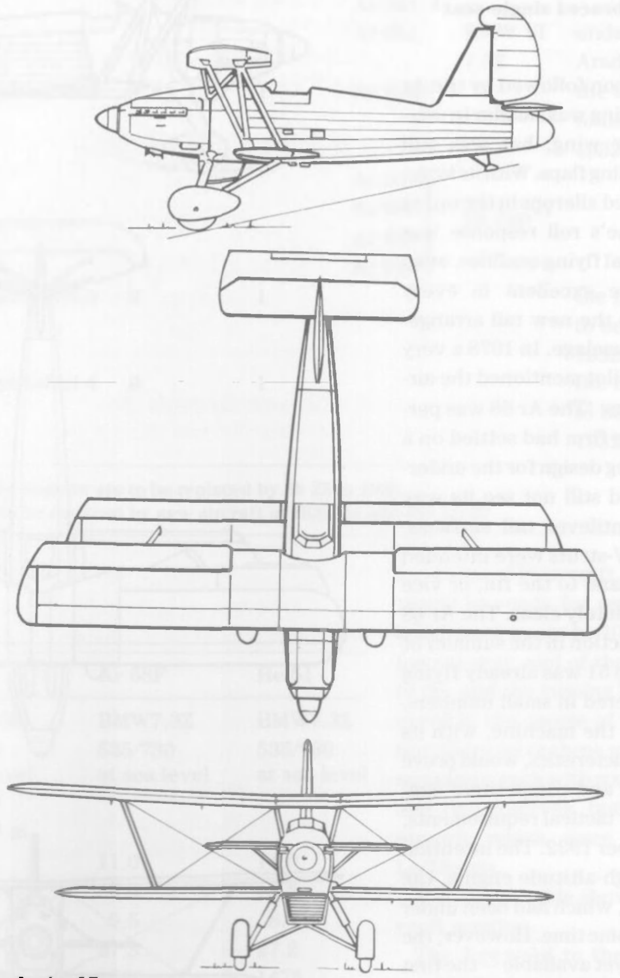
The lower wing of the Ar 67 was larger than on previous Arado fighters built for the Reichswehr. The reasoning behind this change was that the landing flaps, which extended over the entire span, would be

Arado Ar 67.

more effective if the wing were longer. Ailerons were fitted to the upper wing only, but although of generous dimensions, they were not sufficiently powerful to overcome the roll damping of the relatively large lower wing, and roll response was inadequate. One notable innovation was the tail arrangement, where the fin was set forward of the tailplane; this was to become a characteristic feature of all Arado's single-engined aircraft.

This tail layout was designed to avoid the fin being blanketed by the tailplane in a spin. The Arado arrangement, in conjunction with an adequately large fin, proved to be *the* safe means of recovering from a spin. The only alternative was to mount a large part of the fin below the tailplane, a solution which is not always ideal, especially on jet aircraft. Inexplicably, the Arado design found few imitators, although 25 years later the long-time technical director of the Italian firm Aermacchi spoke to the author, and described the tail arrangement of his MB.326 trainer, which had become famous for its good flying qualities, as the 'Arado arrangement'

The power plant for the Ar 67 was a Rolls-Royce Kestrel, which produced 525 hp at full revolutions on the ground and 640 hp at an altitude of 4,200 m. Unfortunately, since the engine was driving a fixed-pitch propeller designed for a speed of 350 km/h at 4,000 m altitude, the speed fall off of the motor at ground level was so great that much less than the 525 nominal horse power was available. The result was that the aircraft's performance either at take-off or in terms of speed — except at altitude — was not convincing. Only one example was built.

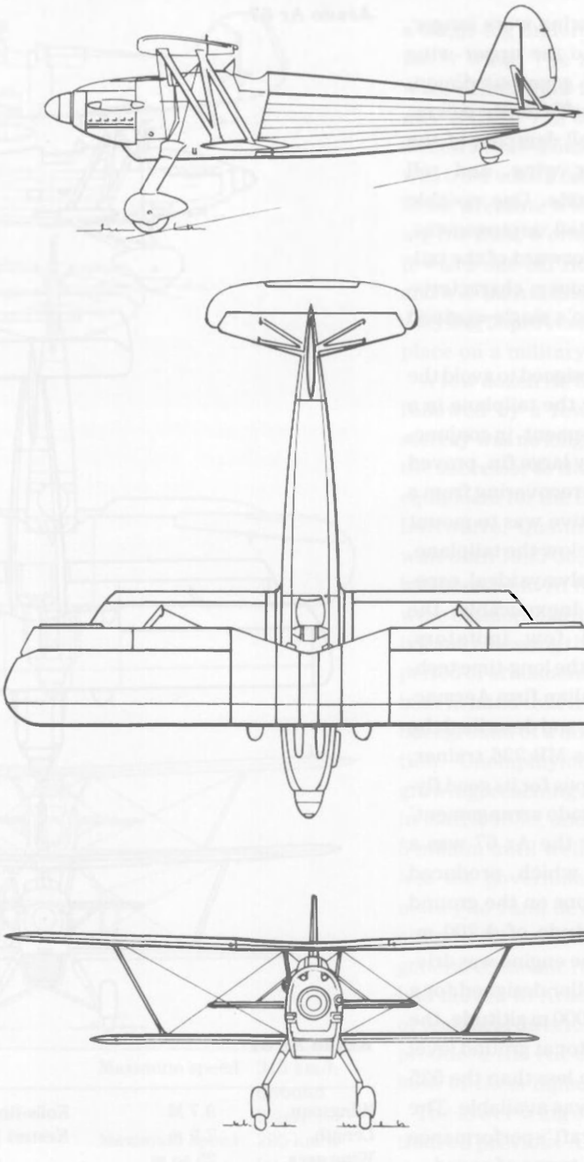


Arado Ar 67

Wingspan	9.7 M	Rolls-Royce Kestrel VI	520 hp at ground level
Length	7.9 m		640 hp at 4,200 m
Wing area	25 sq m		
Empty weight	1,325 kg		
All-up weight	1,760 kg		

Arado Ar 68 with Junkers-Jumo 210 engine, the successor to the He 51, the last German wire-braced single-seat biplane fighter.

The Ar 67 was soon followed by the Ar 68, whose lower wing was smaller in relation to the upper wing, but was still equipped with landing flaps. With its large, effectively balanced ailerons in the upper wing, the machine's roll response was good, and its general flying qualities, even in the spin, were excellent in every respect, thanks to the new tail arrangement and longer fuselage. In 1978 a very experienced test pilot mentioned the aircraft in his memoirs: 'The Ar 68 was perfection to fly'. The firm had settled on a cantilever single-leg design for the undercarriage, but could still not see its way clear to build cantilever tail surfaces. Whether the two V-struts were intended to brace the tailplane to the fin, or vice versa, is not completely clear. The Ar 68 was under construction in the summer of 1933, when the He 51 was already flying and had been ordered in small numbers. It was hoped that the machine, with its reliable flying characteristics, would prove to be a successful and competitive contender for the new tactical requirements, laid down in October 1932. The intention was to install a high-altitude engine, the Junkers-Jumo 210, which had been under development for some time. However, the Jumo 210 was not yet available — the first experimental installation in a Junkers-W 34 was not made until the summer of 1934 — and the first of the three prototypes ordered was fitted with the BMW VI. The result was that the aircraft's performance was the same as that of the He 51; it could hardly have been different. The



Arado Ar 68

two machines were practically identical in terms of drag, and both firms exaggerated their performance figures equally.

Arado got it right with the Ar 68's reliable flying characteristics. It turned out to be an easy to fly, docile aircraft; this could not be said wholeheartedly of the He 51. As late as 1936 Heinkel lost an experienced test pilot in an accident; with the He 51 in a flat spin, he was forced to bale out, and struck the tail. With its larger, well-balanced ailerons the Ar 68 was also superior in terms of roll response, with the result that the procurement programme was reversed in 1936. Most fighter squadrons were equipped with the Ar 68. Udet, who had been second only to Baron von Richthofen with 62 kills, had just been promoted Chief of the Technical Office LC with the rank of colonel; he was a proponent of the idea of the standard fighter aircraft, and did not make the decision lightly. He took one of the best of the younger military pilots to Brandenburg, where Arado was making the He 51 under licence. Samples of the Ar 68 had been brought from the Arado factory at Warnemünde. In front of the Inspector of Flight Safety and Equipment, the machines were flown by Udet, the Arado chief test pilot Kurt Starck, and the Luftwaffe Captain, for the best part of the day, switching from aircraft to aircraft, so that reliable information was available for the decision. But this belongs in the next armament period, which began in 1933 and was planned in 1932.

That the beginning of this armament period coincides with the start of the Third Reich is a coincidence which could not have been foreseen when the sequence of four-year plans, or armament periods, as they were termed, was laid down in 1923. The 1932 plan, which was still very moderate in scope, was not due to be revised until 1934. Before we deal with the new plan, let us take a look at the existing situation, *i.e.* the state of Germany's aircraft strength in February 1932.

Existing Fighter Stocks and the 1932 Plan

It had been decided that the majority of military aircraft available in time of war should be allotted to the reconnaissance squadrons, of which eight were planned, each with six machines and one reserve,

	Aircraft (planned)		Aircraft		
Formation	Front	Store	Type	Engine	Condition
Jagdstaffel 1	9	1	SDIIa		unusable
			SDIII		
			Ar 64a	Sh Jup*	
			Ar 64a		
			Ar 64a		
			Ar 64a		
			Ar 64a		
			Ar 64a		
			Ar 65a	BMW VI 7.3Z	under construction at Arado
Jagdstaffel 2	9	1	Ar 64b		the missing 5 aircraft to be procured in 1932
			Ar 64b	Sh Jup**	
			Ar 64b		
			Ar 64b		
			Ar 64b		
Jagdstaffel 3	9	1			the missing 10 aircraft to be procured in 1932
Jagdstaffel 4	9	1			the missing 10 aircraft to be procured in 1932

* The engines are to be replaced by Sh 22 in 1932.
** To be replaced by new aircraft in 1932, as also the SD III

i.e. a total of 56 aircraft, of which only half would be ready for service. The fighter contingent was to be 40-strong by the following year, and of these 14 were ready to fly, and the missing 26 were to be procured in the course of the year. In addition there were three more night bomber squadrons each with six front-line aircraft and two reserves, but these were civil aircraft which were in service with Lufthansa.

The above table shows the fighter aircraft position.

The foreword to the tactical requirements which were to be laid down during the course of the year is as follows (abbreviated, and omitting four special Navy requirements):

'The tactical requirements of the armament period 1927-32 were as follows:

Arado Ar 68

Specification and comparison with He 51

	Ar 68E	Ar 68F	He 51
Engine	Jumo210E	BMW7.3Z	BMW7.3Z
Power (kW/hp)	500/680 at sea level 490/670 at 3,800 m	535/730 at sea level	535/730 at sea level
Span of upper wing (m)	11.0	11.0	11.0
Span of lower wing (m)	8.0	8.0	8.6
Length (m)	9.67	9.5	8.4
Wing area (sq m)	27.3	27.3	27.2
Empty weight (kg)	1600	1580	1475
All-up weight (kg)	2020	2000	1910
Fuel capacity (l)	200	200	210
Maximum speed — sea level (km/h)	305	330	330*
Maximum speed at 4,000 m (km/h)	325	305	310*

* In production version with the 'saxophone' exhausts, double undercarriage bracing wires, etc.: speed reduced by about 15 km/h.

1. Short-range reconnaissance aircraft, doubling as artillery aircraft and night reconnaissance aircraft,
2. Long-range reconnaissance aircraft doubling as day bombers,
3. Two-seat fighters for day and night,
4. Single-seat fighters for day and night (experimental type),
5. Night bombers.

In addition (for the Navy):

10. Dive bombers,

And for combined Army and Navy service:

11. Training aircraft for pilot and observer trainees,
12. Training aircraft for advanced pilots and observers.

In the meantime it is essential that the number of aircraft types be reduced, because of the constraints placed upon industry by the requirements of series production. This will be facilitated by the experience gained through development work, through knowledge of foreign developments, through the exchange of ideas between all participating and interested parties. The following are the suggested tactical requirements for aircraft types for the armament period 1933-38.

The following had been suggested:

1. Short-range reconnaissance, doubling as artillery aircraft doubling as night reconnaissance aircraft, doubling as training aircraft for advance pilots and observers
2. Two-seat fighter for day and night, doubling as long-range reconnaissance aircraft doubling as light bomber
3. Single-seat fighter for day and night,
4. Heavy bomber,
5. Training aircraft for pilot and observer trainees.

The same aircraft, fitted with floats, are also to undertake special naval duties, with the exception of the two-seat fighter, which is to be built as a land-based aircraft only. It will serve as a dive bomber in the Navy.'

The procurement plans in force at the end of 1932 were as below:

Fighter Aircraft Requirements 1932

In October 1932 the tactical requirements for the armament period 1933-37 were approved. In the fighter aircraft section they defined the 'armament aircraft II' — a two-seat fighter — and the 'armament aircraft III' — a single-seater.

These tactical requirements did not result directly in any new aircraft, but they certainly exerted a considerable and not always favourable influence on the specification for dive bombers laid down in 1934. One interesting feature of these requirements was an expected top speed of 310 km/h for a single-engined two-seater, even though the current single-seaters were no faster than 245 km/h (Arado 65 with RMW VI) at at altitude of 6,000 m, and 282 km/h at sea level. Even the next generation of fighters with the BMW VI (He 51 and Ar 68) could not exceed 310 km/h at full throttle in level flight at sea level, bearing in mind that the usual 5 per cent tolerance has to be deducted from company figures. This corresponds to about 270 km/h at 6,000 m altitude. To achieve the required maximum speed would have called for an increase in power of 35 per cent at 6,000 m, not to

'Aircraft re-armament programme in the period 1933-37'

	At the end of the period 1927-32 the following are available	To be procured	Final total
Fighter formations		24	72
Material reserves	Fighter aircraft	27	27

Tactical requirements for the re-armament aircraft II

1. Tactical application:	a) two-seat fighter:	1.) aerial combat, day and night 2.) low-level attack
	b) reconnaissance aircraft operations:	Operational and tactical air reconnaissance, day and night
	c) light bomber:	1.) bomb dropping, day and night, high- and low-level attack 2.) release of chemical weapons at low level.
2. Number of engines:	1	
3. Crew	1 pilot 1 observer/gunner	
4. Armament	a):	2 fixed machine-guns, 500 rounds per barrel 2 movable machine-guns, 750 rounds
	b) and c):	1 fixed machine-gun, 500 rounds 1 movable machine-gun, 750 rounds
5. Bomb-dropping equipment:	a):	for 12 × 10 kg bombs or 120 kg: fire bombs
	b):	—
	c)1):	250 kg normal load, consisting of 10 kg bombs, 50 kg bombs, fire bombs, also mixed load as far as possible. For short-range attack, maximum possible use of load-carrying capability in form of bomb load.

for maximum flight range

	c)2):	One tank for chemical weapons
Sighting apparatus:	optical:	only for day use by formation leader and second-in-command
	mechanical:	for day use by formation sub-leader
		for night use — all aircraft.
6. Communications and reporting equipment:		As per section 5 of the tactical requirements for aircraft-ground and aircraft-aircraft communications, also signal lamp equipment. Simple optical and acoustic means for communication within aircraft.
7. Safety and rescue apparatus:		Safety harness Parachutes Fire extinguisher First-aid pack High-altitude oxygen equipment
8. Speed:	a) and b):	280 km/h at 6,000 m c): at least: 250 km/h at 6,000 m
	a) and b)	310 km/h at 6,000 m c): at least 280 km/h at 6,000 m
9. Range and duration	a):	2 hours full-throttle at 6,000 m altitude
	b) and c):	1,000 km
10. Climb performance	a):	6,000 m in 12 minutes
	b):	6,000 m depending on the increased payload
	c):	6,000 m depending on the increased payload
11. Range of working altitude:	a)1):	to 9,000 m
	a)2):	below 100 m
	b):	6,000-9,000 m
	c)1):	500-7,000 m (high-altitude attack) under 100 m (low-level attack)
	c)2):	below 100 m
12. Airfield size (normal German day)		take-off and landing strip:
	a) and b):	150 × 300 m c): 200 × 400 m
		approach distance up to 20 m altitude
	a) and b):	400 m c): 600 m

13. General notes:

Re. No. 1: Tactical operations for tasks a), b), c)1) and c)2) will be made in organisationally separate formations. Aircraft a), b), c)1) and c)2) are identical in structure, and differ only in equipment.

Re. No. 2: Noise muffling is required for the engine, also exhaust flame damping for night flying.

Re. No. 5: The bomb release is operated by the pilot of a two-seat fighter, by the observer of a bomber.
The chemical weapons release is operated by the observer of a bomber.
It must be possible to check release of the bombs from the aircraft.
Emergency release system must be provided.
It must be possible to load the maximum bomb load in less than 15 minutes; the same applies to installing the chemical weapons tank.

Re. Nos. 8-12 *Re. flying performance and characteristics:*
The performance required, and the underlying airframe strength, apply to the aircraft with payload, without bomb load (two-seat fighter), to the aircraft with full payload (reconnaissance aircraft), to the normal payload (bomber). It must be within the capability of any average pilot.
Where the leader aircraft of bomber formations must carry an increased payload in aiming apparatus, additional radio and photographic equipment, compared with the standard aircraft, a corresponding decrease in bomb load is permitted.
The aircraft must be capable of maintaining maximum speed at working altitude for up to 20 minutes duration.
If the aircraft is capable of a spin at all, it must be easily possible to recover from the spin.
It must be possible to fly turns within the working altitude range without loss of height.
Two-seat fighters and bombers must be capable of squadron take-off and landing (up to 9 aircraft).

Re. No. 9: The required flight range is to be understood as follows:
a): Total flight duration at 6,000 m working altitude climb and glide from take-off to landing.

	b): Reaching working altitude of 7,000 m before crossing the Front, flying at this altitude at cruising speed over the enemy and back to base, gliding to the landing site. Distance of take-off and landing site from the Front: 50 km.
	c): As b), but with normal bomb load for day operations (250 kg).
Re. No. 12:	The longer field dimension is in the direction of the prevailing wind; the approach area adjoins the field on both sides.

mention the extra necessitated by the larger size of a two-seater compared with a single-seater. Such an increase would have necessitated a supercharged engine. Work on this type of engine had been in progress for some time, but there was no chance that it would be available before the end of the armament period.

A further significant part of the requirement for the principal naval task (dive bomber) ran:

'Dive inclination of 70 to 90 degrees with a 500 kg bomb, complete safety at terminal speed in the dive, and safe recovery at maximum load'

It is clear that Ernst Udet was not, as is generally claimed, the originator of the dive bomber, although he indisputably played a decisive role in the development of the type. (American feature films had done much to popularise the concept several years before.)

In addition to the ability to carry a 500 kg bomb which could be released in a dive, the Army demanded a further innovation: the ability to 'release light splinter bombs against an aircraft formation flying 800-1000 m lower'.

Noise reduction and flame damping were among the requirements for aircraft engines; years later these demands were still giving aircraft design engineers headaches. The size of the airfield area, which determined the necessary take-off and landing characteristics and performance, sound surprisingly modest. It seems highly unlikely that squadron take-offs and landings could be made by nine aircraft from such a small area. The tight restriction on airfield dimensions meant that it was difficult to increase wing loadings; as a result, the aircraft designer was denied one of the main means of increasing performances.

Tactical requirements for the re-armament aircraft III

1. Tactical application	Single-seat fighter
2. Number of engines:	1
3. Crew:	1 pilot
4. Catapult capability:	—
5. Armament	either: 2 fixed machine-guns, 500 rounds per barrel and 4 × 10 kg bombs (see note No. 14, ref. 1) or: 1 fixed machine-cannon, 200 rounds
6. Bomb-dropping equipment:	1.) For 4 × 10 kg bombs (for release from low-flying formation) 2.) For 9 × 10 kg bombs (normal equipment. For short-range attack, maximum possible use of load-carrying capability in form of bomb load (10 kg bombs).
Sighting apparatus:	1.) For the release of light splinter bombs against enemy formations flying 800-1,000 m lower 2.) —
7. Speed:	Maximum: 350 km/h at 6,000 m
8. Range and duration:	1½ hours full-throttle at 6,000 m
9. Climb performance:	6 km in 8 minutes
10. Working altitude range:	1.) up to 9,000 m 2.) below 100 m
11. Airfield size (normal German day):	Airfield size: 150 × 300 m Approach distance at up to 20 m altitude: 400 m
12. General notes:	
Re. No. 1:	Tactical operations for tasks 1) and 2) are to be made in one and the same formation.
Re. No. 2:	Noise muffling is required for the engine, also exhaust flame damping for night flying.
Re. No. 3:	Optimum viewing conditions for aerial combat and low-level flight.
Re. No. 5:	The weapons installation must be designed to ensure the best possible field of fire, and ease of handling.
Re. No. 6:	It must be possible to check release of the bombs from the aircraft. Emergency release system must be provided.

Re. No. 7-11: *Concerning flight performance and characteristics:*
The performance required, and the airframe strength, apply to the aircraft for application 1) and armed with 2 fixed machine-guns and 4 × 10 kg bombs; it must be within the capability of any average pilot.
The required flight range is to be understood as follows:
Total flight duration at 5,000 m working altitude including climb and glide from take-off to landing.
The aircraft must be capable of maintaining maximum speed at working altitude for up to 20 minutes duration.
If the aircraft is capable of a spin at all, it must be easily possible to recover from the spin.
It must be possible to fly turns within the working altitude range without loss of height
Performance is to be assessed with the following priority:
1.) climb speed
2.) manoeuvrability
3.) level flight speed
Aircraft must be capable of squadron take-off and landing (up to 9 aircraft)
The longer field dimension is in the direction of the prevailing wind; the approach area adjoins the field on both sides.

Other matters: Flying in fog and cloud must be possible for both tasks.
When dismantled for transport, the aircraft must meet the rail transport conditions (normal profile)

Tactical Requirements for the Single-seat Fighter

The tactical requirements for the armament aircraft III dictated a machine of similar design to the Arado Ar 68, apart from the required maximum speed of 350 km/h at 6,000 m, which, moreover, was to be maintained for up to 20 minutes' duration repeatedly. As was the case with the two-seater, a much more powerful engine would be required to achieve this performance. However, maximum speed does not seem to have been all that important to the authors of the requirements, since they had laid down the performance parameters in the following sequence:

1. Rate of climb
2. Manoeuvrability
3. Level flight speed

With the exception of maximum speed and a lift-off speed of no more than 110 km/h, no figures were attached to these requirements. The poor aircraft designer was faced with the task of building an aircraft which could climb as fast as possible, was as manoeuvrable as possible, and possessed a maximum speed which on the one hand could not be achieved with the power plants available, and on the other hand was incompatible with the aircraft's stalling speed. Squadron take-offs and landings involving nine aircraft were to be possible from a field 150 by 300 m in area. It was also a requirement that the fighter could be converted into a seaplane by replacing the undercarriage with floats.

The requirements for the single-seater's spinning characteristics were the same as for the two-seater: 'It must be easily possible to recover the aircraft from a spin, if it can be made to spin at all.' This was a somewhat cryptic requirement, as it is not clear whether it was sufficient to ensure that the aircraft could recover immediately after the spin had set in, whether it could recover after several turns of a fully developed spin; the difference between the two is immense.

One significant part of the specification for the armament aircraft III — the single-seat fighter) was that the armament was to consist of two fixed machine-guns with 500 rounds each or one fixed machine cannon with 200 rounds. This was the first time that a fighter's armament was to include a cannon. In consequence, the 20-litre engine under development at Junkers was planned with the ability to fire through the hollow propeller shaft.

As was the case with the armament aircraft II — the two-seat fighter — no new design for the armament aircraft III — the single-seat fighter — was produced as a direct result of these tactical requirements.

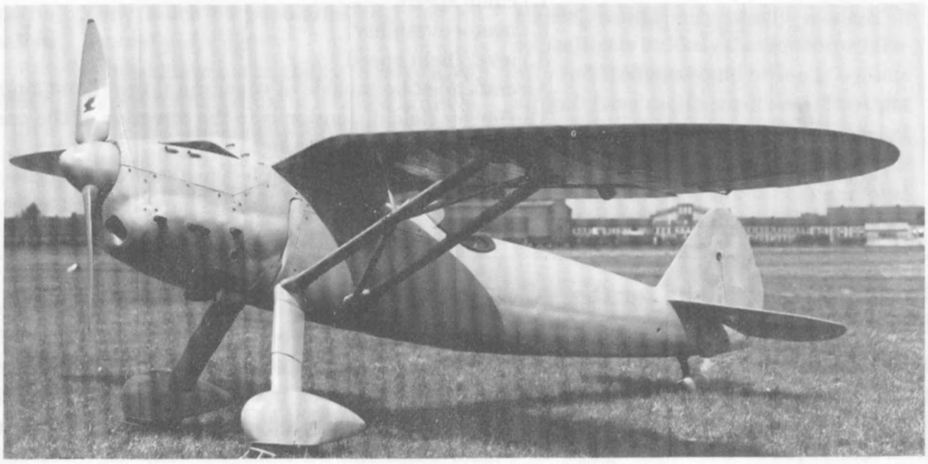
Heinkel He 70, six-seat transport aircraft, which was 50 km/h faster than the fighter with the same engine.

Henschel Hs 121, single-seat 'home guard' fighter trainer.

P.Z.L. P.24

Wingspan	10.6 m
Length	7.5 m
Wing area	18 sq m
Empty weight	1,270 kg
All-up weight	1,775 kg
Gnome-Rhone Jupiter	800 hp at 4,400 m
Maximum speed	404* km/h at 4,500 m
Rate of climb	8.0* min to 6,000 m

*P.Z.L. Figures



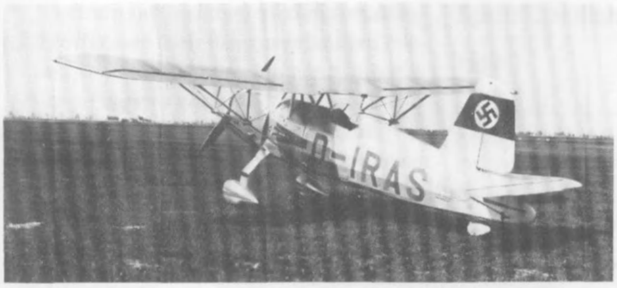
ments. However, they probably served to justify further work on the Heinkel He 51 and the Arado Ar 68. It must have become clear to the authorities that the means available for development were too restricted to allow any major advance. It seems likely that the performance and speed range achieved by light aircraft in civil competitions had been the basis for these requirements. Civil aviation had long since left military aircraft behind in technological terms. The competitors in the Sachsenflug — a technical light aircraft competition — were without exception monoplanes, almost all of them of cantilever design. Albatros and Heinkel, who were still steadfastly building braced biplanes to fulfil their Reichswehr contracts, were also developing cantilever monoplanes for non-military use. A notable example was the Heinkel He 70, which was more than 50 km/h faster than the current single-seat fighters, despite the fact that it was powered by the same engine — the BMW VI — and could carry six persons. The aircraft set up three class records after mid-March 1933, culminating in a speed record of 355.3 km/h over a distance of 500 km carrying a payload of 1,000 kg, achieved on 28 April, 1933, five months after its first flight (1 December, 1932). Naturally the fighters could outclimb and out-turn the He 70, but they could not catch it up[10]. Indeed, a twin-engined aircraft of twice the size and a payload capacity of two tons was under development for Lufthansa, and it was evident that it could easily be converted into a bomber with a similar performance. Eventually, in 1933, the military was forced by these developments to undertake a complete revision of aircraft development plans.

Fighter Development 1933-1939

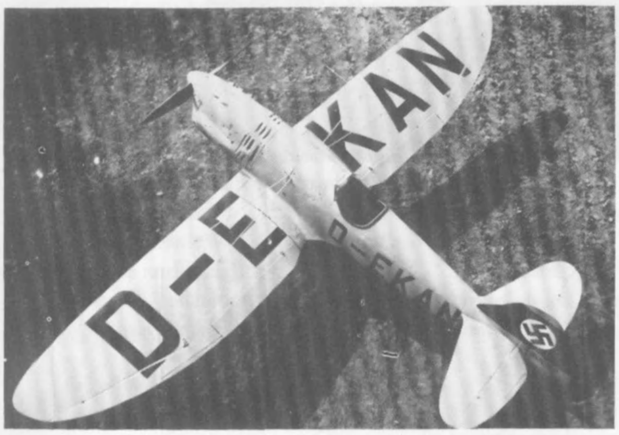
On 30 January, 1933, Hitler, as leader of the largest party, was appointed Reichs Chancellor. Three days later, on 2 February, 1933, Herrmann Göring was nominated Reichs commissioner for aviation. Göring was one of Hitler's closest associates, and had been the last leader of the Richthofen Jagdstaffel, during which time he had been awarded the Pour-le-Merite. Shortly afterwards, on 27 April, 1933, the aviation commissariat became the Reichs Air Ministry, and absorbed the air defence office, which had previously been the overall authority for Army and Navy aviation.

The Air Ministry was only loosely organised at first, but it was revised and consolidated to some extent on 1 September, 1933. One feature of the reorganisation proved important in terms of promoting technical development: the LC Technical Office, known as the C-Office, which was in overall charge of technical development, became an independent body, accountable to the Minister and his Secretary of State, Milch. In addition to his office of Reichs Minister of Aviation, Goring held the offices of Prime Minister of Prussia and Interior Minister. These changes made the task of restoring life to the aviation industry much easier, especially on the military side, and ensured that development plans would be achieved.

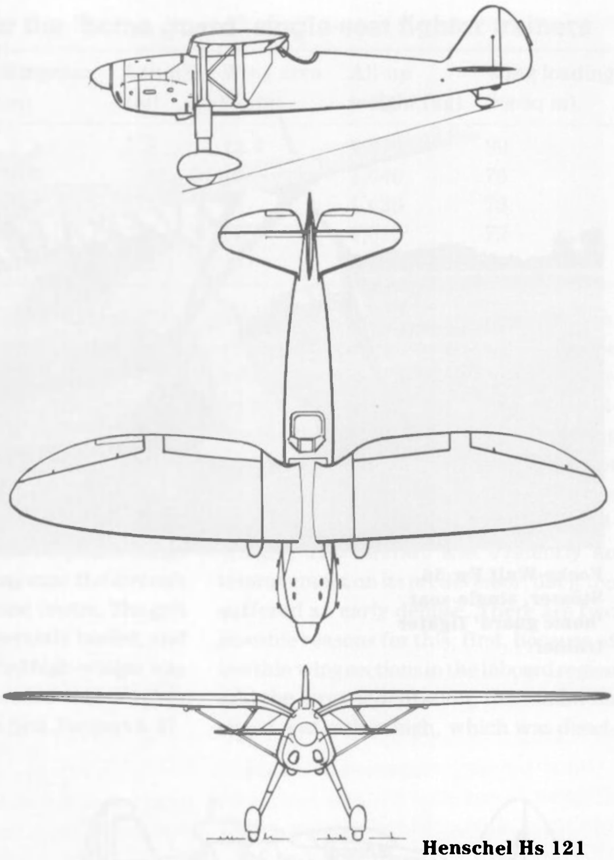
If the plans for the Luftwaffe were to be realised as rapidly as possible, the training of personnel was just as important as the procurement of aircraft. Aircraft were required for training flight crews and for practice flying, but none of the trainers available at the time met the needs of the military. Contracts were immediately awarded to Arado, Focke-Wulf and Heinkel to produce an initial training aircraft. The result was three biplanes of identical dimensions and weights: all three were 9.0 m in wingspan, about 7.5 m long and had a wing area of 20 sq m; all three had a flying weight of around 850 kg with



Arado Ar 76, single-seat 'home guard' fighter trainer.



Henschel Hs 125, single-seat 'home guard' fighter trainer.



Henschel Hs 121

two occupants, and were powered by engines producing 150 hp. As such they had similar specifications to the fighters of 1916-17, but they were much easier to fly and more manoeuvrable. The Arado machine had a rather small fin and tended to oscillate around the yaw axis. By the time this defect had been corrected the contracts had long since been awarded. The Focke-Wulf Stieglitz (Goldfinch) and Heinkel Kadett were to be the aircraft on which the next generation of pilots was to learn to fly over the next few years.

The first flight of the Heinkel Kadett was made by the later General Junck, Jafü 3 (fighter chief) in the Battle of Britain. At the time, Walter Gunter, one of the twin brothers who directed the design office at Heinkel, asked me whether I liked the aircraft. I replied: 'Not at all! I would have designed a low-winger with side-by-side seats [11]'. Gunter laughed ironically: 'That would have pleased the Ministry! They wanted a biplane. If the pilots have to fly a biplane fighter, they may as well learn to fly a biplane.'

The Single-seat Fighter Trainer (Home Defence)

Hardly had the requirements for the beginner's trainer aircraft been laid down than the plans were drawn up for a single-seat trainer for advanced pilots.

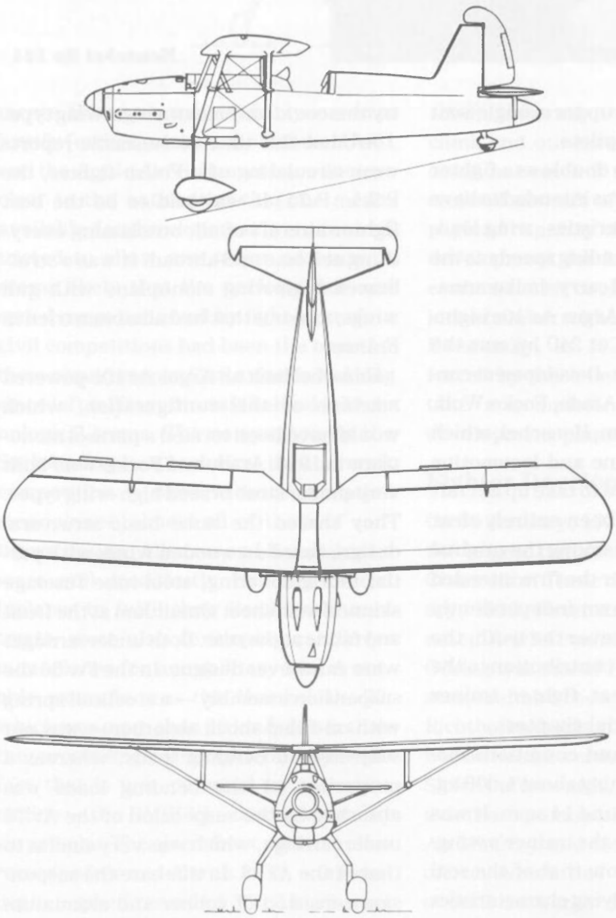
This machine was to double as a fighter for target defence. It was intended to have similar flying characteristics, wing loading and take-off and landing speeds as the single-seat fighter, and carry similar armament. The air-cooled Argus As 10c eight-cylinder engine rated at 240 hp was the prescribed power plant. Development contracts were granted to Arado, Focke-Wulf, Heinkel, and a new firm, Henschel, which was actually a machine and locomotive company which wanted to take up aircraft building. It has never been entirely clear whether Heinkel was among the original contractors, or whether the firm intended to compete with its own independently developed type. Whatever the truth, the history of the Heinkel contribution to the saga of the single-seat fighter trainer deserves its own special chapter.

The requirements and conditions dictated an aircraft weighing about 1,000 kg, *i.e.* a wing area of around 14 sq m. It was important not to allow the trainer's wingspan to fall much below that of the real fighter, otherwise its flying characteristics would be too different, and with this in mind the only practical solution was the monoplane, and in the eyes of the Ministry this could only mean a high-wing type.

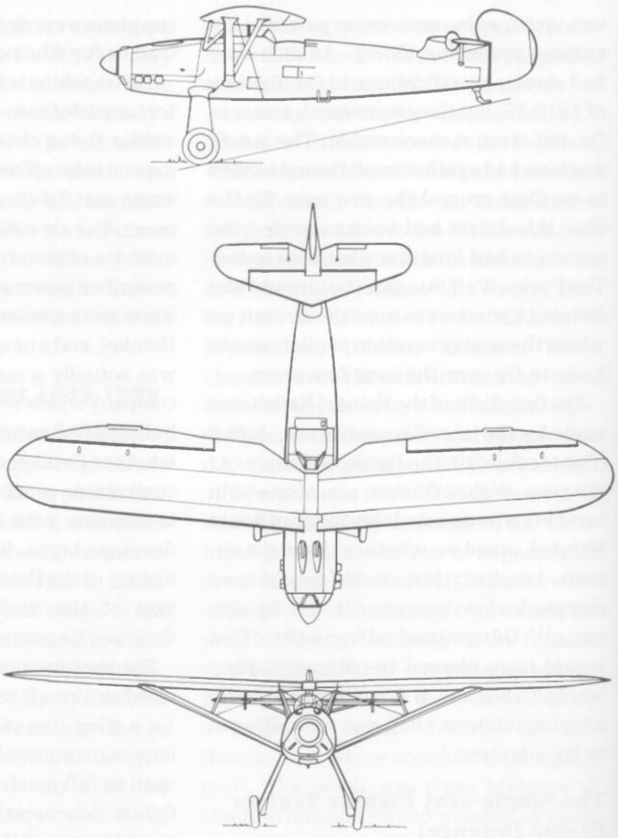
Around this time enthusiastic reports were circulating of a Polish fighter, the P.Z.L. P.24. It was said to be the best fighter aircraft of all, outclassing everything at home and abroad. It was a strut-braced high-wing monoplane with gull wings, a layout that had also been tried in France.

Henschel built an Argus As 10c-powered machine of this configuration, which would have been termed a parasol monoplane in 1914. Arado and Focke-Wulf built very similar strut-braced high-wing types. They shared the same basic structural design, based on wooden wings with partial fabric covering, steel-tube fuselage skinned with sheet aluminium at the front and fabric at the rear. Both undercarriages were cantilever designs. In the Fw 56 the suspension assembly — a steel coil spring with oil-filled shock absorber — was not subjected to bending loads, whereas a proportion of the bending loads was absorbed by the suspension of the Ar 76 undercarriage, which was very similar to that of the Ar 68. In this case the suspension consisted of rubber and aluminium discs which were capable of absorbing compressive loads, and an oil-filled shock absorber.

Focke-Wulf Fw 56 Stösser, single-seat 'home guard' fighter trainer.



Arado Ar 76



Focke-Wulf Fw 56 Stösser

Both aircraft had their teething troubles. In both cases their designers had not realised that the wing struts constituted a form of narrow wing, and hence might be subject to problems such as wing flutter and critical speeds. After these problems had been eliminated, both proved to be outstandingly pleasant to fly. The Arado Ar 76 in particular could be flown in a straight line with great precision, without the slightest tendency to wander. This was a highly desirable characteristic for gun aiming and firing. The Focke-Wulf Fw 56 Stösser (Hawk) had no fin in the usual sense, just a vestigial post and a fairly large rudder. Its directional stability was not quite so good, and it also lacked the same outstanding spin qualities. The Arado was faultless in this respect, as a pilot could recover even from an inverted spin by releasing the stick.

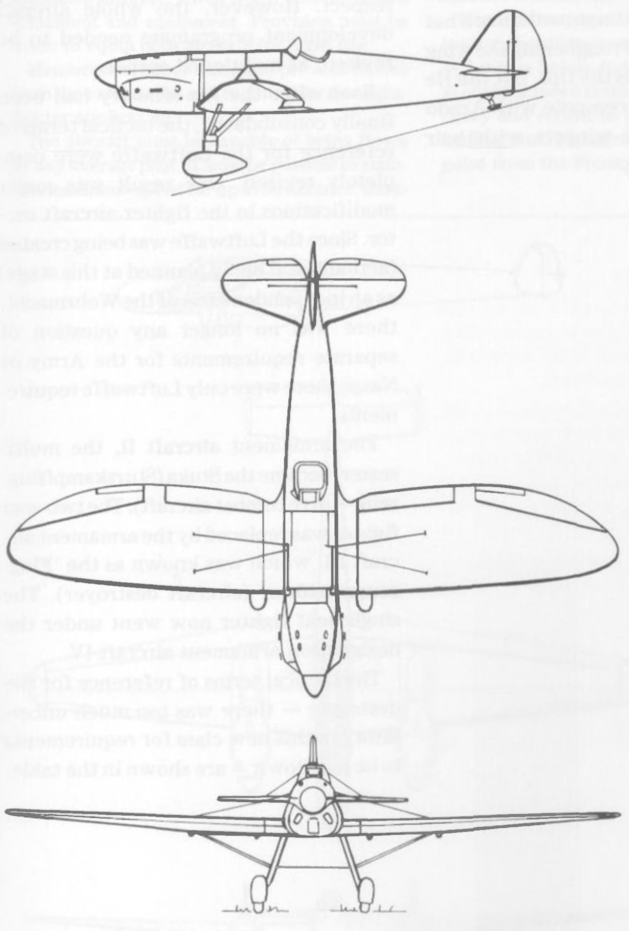
The two aircraft had virtually identical dimensions and weights.

The Fw 56, with its rounded contours, had a slightly more pleasing appearance, and in this case attention to styling seems to have paid off, as it was ordered in larger numbers.

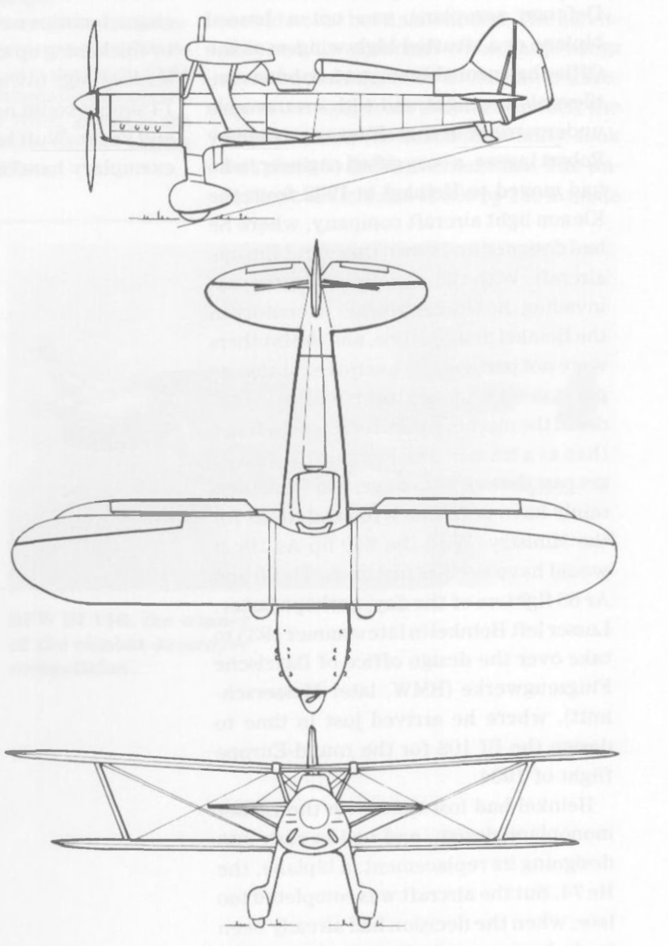
Specifications for the 'home guard' single-seat fighter trainers

Type	Wingspan (m)	Length (m)	Wing area (sq m)	All-up weight (kg)	Wing loading (kg/sq m)
Arado Ar 76	9.8	7.2	13.4	1,070	80
Focke-Wulf Fw 56	10.5	7.65	14	1,040	75
Henschel Hs 121	10.0	7.3	14	1,020	73
Henschel Hs 125	10.0	7.3	14	1,010	72
Heinkel He 74	8.2/7.0	6.5	15	1,020	68

The Henschel entry, the Hs 121, looked extremely attractive. However, the machine seems to have had some sort of fault or peculiarity. What was actually wrong has never been made known; there is a strong temptation to sweep such things under the carpet. In any case the aircraft never got as far as the test centre. The gull wing was quietly and secretly buried, and in short order the strutted high-winger was transformed into a braced mid-winger, similar in layout to the first Junkers K 47. The fuselage, tail, undercarriage, engine, etc. remained unchanged, and only the inboard part of the wing and its attachment to the fuselage and the corresponding bulkheads were different. The wing outline with the deep scallop in the root trailing edge was also retained, even though it was not necessary in a mid-winger. The aircraft was evidently an improvement on its predecessor, but it too suffered an early demise. There are two possible reasons for this: first, because of the thin wing sections in the inboard region and the large indentation, the minimum speed was rather high, which was disad-



Henschel Hs 125



Heinkel He 74

Henschel He 74, single-seat 'home guard' fighter trainer.

vantageous in terms of take-off and landing run, manoeuvrability, turn radius, etc.; second, it is difficult to imagine that an all-metal trainer would have been acceptable at that time in any case.

Heinkel's first suggestion for a Home Defence aeroplane was not a braced biplane or a strutted high-winger, as the Office had probably suggested, but a cantilever low-winger, and with a retractable undercarriage at that. It was designed by Robert Lusser, a very gifted engineer, who had moved to Heinkel in 1932 from the Klemm light aircraft company, where he had designed and flown the round-Europe aircraft. With the new design Lusser was invading the Gunter brother's territory in the Heinkel design office, and the brothers were not particularly overjoyed at this, to put it mildly. Lusser had probably considered the machine more for Home Defence than as a trainer. The low-winger did not get past the mock-up stage, and would certainly have been much too ambitious for the Ministry. With the 240 hp As 10c it would have been as fast as the He 50 and Ar 68 fighters of the day, perhaps faster. Lusser left Heinkel in late summer 1933 to take over the design office of Bayrische Flugzeugwerke (BMW, later Messerschmitt), where he arrived just in time to design the Bf 108 for the round-Europe flight of 1934.

Heinkel had lost time with the Lusser monoplane design, and had to rush into designing its replacement: a biplane, the He 74. But the aircraft was completed too late, when the decision had already been made. In any case the He 74 had downright vicious tip-stall tendencies at first. If it was stalled, the aircraft spontaneously rolled inverted. The aircraft had thin wing sections, and the prototype was built with ultra-smooth surfaces, with the result, as we would say today, that the laminar airflow over the wing separated at the stall, and lift was lost at the wingtips. The stall characteristics were improved somewhat by thickening up and roughening the wing leading edge towards the tips, but the He 74 simply could not compete with Arado and Focke-Wulf high-wingers, with their exemplary handling.

The Tactical Terms of Reference 1933-34

It was relatively easy to establish the range of duties for the new training aircraft; there was no major controversy in this respect. However, the whole aircraft development programme needed to be revised, as mentioned earlier.

Soon after the Air Ministry had been finally consolidated, the tactical terms of reference for the Luftwaffe were completely revised. One result was major modifications in the fighter aircraft sector. Since the Luftwaffe was being created (actually still being planned at this stage) as an independent arm of the Wehrmacht, there was no longer any question of separate requirements for the Army or Navy; there were only Luftwaffe requirements.

The armament aircraft II, the multi-seater, became the Stuka (Sturzkampfflugzeug — dive combat aircraft). The two-seat fighter was replaced by the armament aircraft III, which was known as the 'Flugzeugzerstörer' (aircraft destroyer). The single-seat fighter now went under the designation armament aircraft IV.

The tactical terms of reference for the destroyer — there was too much uncertainty in this new class for requirements to be laid down — are shown in the table.

Tactical terms for the re-armament aircraft III (1934)

Tactical application:	Aircraft destroyer
Number of engines:	1-2
Crew:	3-4
Armament:	2 × 2 cm cannon/1 twin machine-gun
Safety and rescue equipment:	Self-steering apparatus
	High-altitude oxygen apparatus
	Heating
Speed:	Cruise: 330 km/h at 6,000 m
	Maximum: 400 km/h at 6,000 m
Range:	2,000 km at cruising speed
Climb rate:	6,000 m in 15 minutes
Working altitude range:	up to 9,000 m
Service ceiling:	10,000 m
Airfield size:	500 × 500 m
Other equipment:	Instruments for cloud and fog flying
	Automatic control system
	Landing speed below 100 km/h
Assessment:	a) speed
	b) range
	c) rate of climb
	d) manoeuvrability

The emphasis here is on the 'aircraft destroyer'. The same aircraft type must also be capable of doubling as a high-altitude, long-range reconnaissance aircraft, when fitted with different armament and equipment. Provision must be made to equip both aircraft for night use.

Measures to reduce noise and prevent flames from the exhaust are also required for the night-fighter application.

The aircraft must be capable of being flown by any average pilot. It must be possible to maintain maximum speed for up to 20 minutes' duration at working altitude.

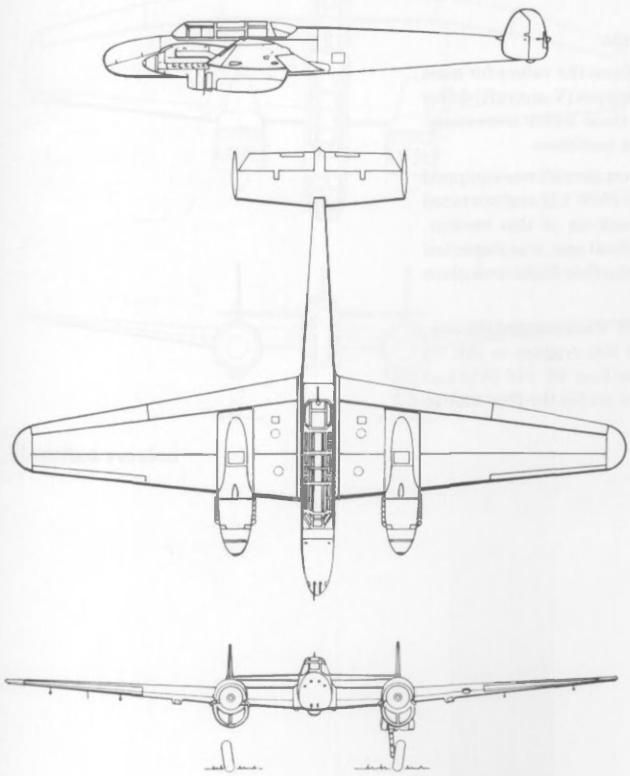
It must be easy to recover the aircraft from a spin. It must be possible to fly turns at working altitude without loss of height.

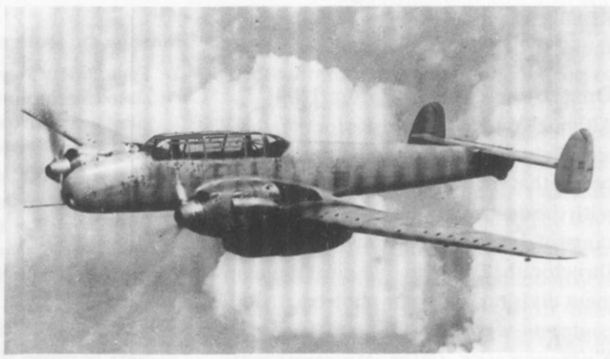
The term 'required flight range' means the following: the ability to achieve a working altitude of 7,000 m before flying over the Front; flight at cruising speed at this altitude over enemy territory and return to the Front, gliding to the landing site. Distance of take-off and landing point from the Front: 50 km.

These terms of reference include a number of important points which were to determine the form of the destroyer aircraft, namely:

1. The aircraft could have two engines,
2. It was to carry a crew of 4 (3),
3. It was to develop its maximum speed at 6,000 m altitude and be able to operate at an altitude of 9,000 m,
4. The range was to be 2,000 km — *i.e.* the ability to penetrate 750-800 km, at cruising speed; this speed corresponded to a throttle position of around ⅔ maximum,
5. The landing was to be less than 100 km/h.

This last requirement — landing speed below 100 km/h — forced the aircraft designers to aim at a wing loading on landing of substantially under 100 kg/sq m, if they were to follow the terms to the letter, unless they introduced complex functions in the wings, which the Ministry would never have sanctioned. The inevitable result was aircraft whose large wings were bound to render them rather unresponsive right from the start. In fact, the requirements for manoeuvrability took last place in the assessment list. The unrealistic airfield size of 300 by 150 m made





BFW Bf 110, the winner of the combat destroyer competition.

way for a site 500 by 500 m, which was more realistic.

The terms of reference made no mention of the gun equipment, whether fixed or partly movable, firing forward or in rotary turrets. Presumably the authors of the specification were expecting rotary turrets, as this is the only way to account for the expected speed difference of 50 km/h between the armed destroyer and the reconnaissance version. In fact, the installation of cannon in rotary turrets was the latest development abroad, and the German firm of Mauser was already working on a rotary turret in case it was required.

The Engines

The power requirements for the destroyer could only be met by using high-altitude engines, *i.e.* units which used a blower to compensate for the fall in inlet pressure with increasing altitude. Such engines were not ready when the requirements were drawn up, but they were in preparation. All three of the major aircraft engine firms — BMW, Daimler-Benz and Junkers — were working on water-cooled twelve-cylinder 20- and 30-litre engines. Eventually a restriction was placed on the number of power plants under development, in order to maximise production capacity. The original intention had been to use the 20-litre unit for the fighter and the 30-litre unit for the bomber. It followed then that the single-seat fighter would be fitted with the 20-litre engine, along with the destroyer.

Destroyer Development 1934

Although the range of duties for the single-seat fighter was fixed about six months before that for the destroyer, we shall deal with the destroyers first. In June 1934 the range of duties was laid down by the Staff Director at LC II, the technical development division in the Air Ministry. In July contracts were awarded to Bayerische Flugzeugwerke (later Messerschmitt), Focke-Wulf and Henschel, to build three experimental aircraft each to the destroyer requirement. Three firms with three experimental aircraft each (Versuchsflugzeuge, or V-aircraft) was the usual development formula at the time. The intended power plants were a pair of the 20-litre Junkers-Jumo 210 engines, producing about 700 hp. BFW developed the smallest of the three machines, the Bf 110, with the Jumo 210. Henschel's Hs 124 was next largest, powered by the Jumo 210 (first version) and the air-cooled BMW 132 (second version). Focke-Wulf built the largest machine, the Fw 57, which was intended for the Daimler-Benz DB 600, but as this engine was not available in time, the British Rolls-Royce Buzzard was installed, as it was similar in size.

It is no surprise that the Jumo 210 engines originally planned were not used in the end. Development work indicated the inevitability of a much larger aircraft than had originally been intended, and hence the need for larger engines. The following table shows the specifications and the history of development of the prototype aircraft which were built to meet the combat destroyer requirement.

A surprising feature in the comparison of these aircraft is the wide variation in wing area and weight — almost 1:2. The difference arose because the designers were aiming at different aspects of the requirements. At BFW it seems that the design engineers did not consider the requirements at all, and simply built the aircraft which they wanted to build. Something seemed to be wrong with the whole idea. Half-way through the destroyer development process official minds also began to have doubts — justified doubts — about the practicality and suitability of an aircraft built to the 1934 terms of refer-

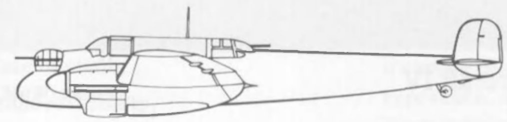
Development history of combat destroyers

Manufacturer Type	BFW Bf 110	Focke-Wulf Fw 57	Henschel Hs 124
Task set by LC II		June 1934	
Task set for companies		July 1934	
Mock-up inspection	February 1935	March 1935	November 1934
First flight	May 1936	May 1936	April 1936
Specification			
Wingspan (m)	16.8	25	18.2
Length (m)	12.6	16.4	14.5
Wing area (sq m)	39	73.5	54.5
All-up weight (kg)	5,700	8,300	7,200
Engine V[1] Jumo	210[3]	DB 600	Jumo 210[2]
Power kW (hp)	2 × 500 (675)	2 × 670 (910)	2 × 500 (675)

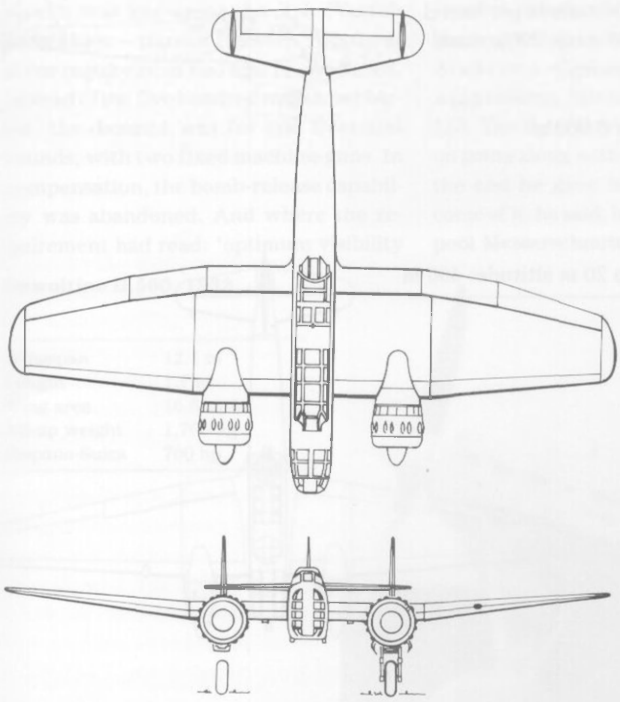
Notes on the above table:

1. For a variety of reasons the values for mass stated for the prototypes (V-aircraft) differ substantially from those which were measured on production machines.
2. The second Hs 124 test aircraft was equipped with two air-cooled BMW 132 engines rated at 870 hp. The mock-up of this version, intended to be the final one, was inspected in March 1935 and the first flight took place in April 1937.
3. In August 1935 BFW was awarded the contract to install DB 600 engines in the V3 machine before the first BF 110 (VI) had flown. It took to the air for the first time in December 1936.

Henschel Hs 124.



First version



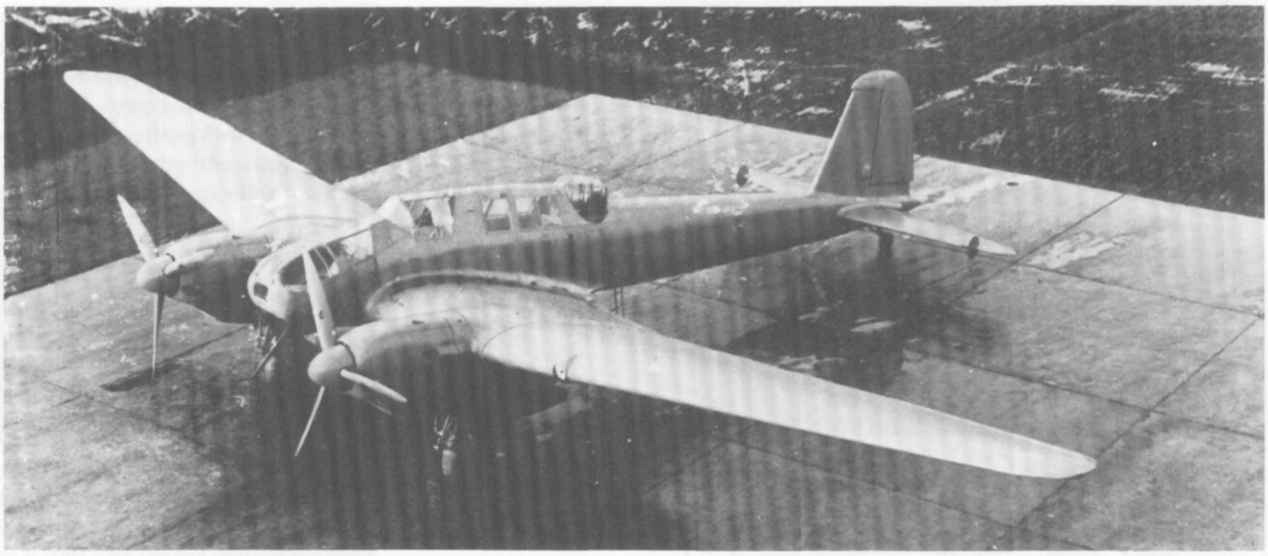
Modified version

ence for the armament aircraft III. The aircraft which had been built within the terms of reference, the Fw 57 and Hs 124 were completed, but in early 1937 it was decided that both aircraft 'were not to be considered for procurement; the zero-series (zero-series was the first production series) will not be built'.

Fortunately the Bf 110 did not disappear along with the concept of the combat destroyer. The aircraft proved to be a powerful, practical machine, which had a long life before it. It was not what the Ministry had wanted, but was better than the Office had imagined. Just six weeks after the first flight the decision was made to procure the machine, and in July a preliminary order for a zero-series of nine machines was awarded, even though the second and third experimental machines did not fly until October and December respectively. More aircraft were demanded: everyone wanted to see what could be made out of it and done with it — high-speed bomber, reconnaissance aircraft, heavy fighter — and it was hoped that the aircraft would be able to play all these roles. The whole concept of Luftwaffe procurement seems to have been rethought. Production of the Junkers Ju 89 Dornier Do 19 heavy bombers was halted in April 1937, just one year after the first flight of the Bf 110; this decision was not made on the spur of the moment, but was the result of long and difficult cogitations. The further development of the Bf, later Me 110, will be described in a later chapter, after we have dealt with the new single-seat fighter, the armament aircraft IV.

The Single-seat Monoplane Fighter 1935-36

The tactical requirements set up in 1933 for the armament aircraft IV, the single-seat fighter, are shown in the following table.



Focke-Wulf Fw 57.

Tactical requirements (Army) for the re-armament aircraft IV (1934)

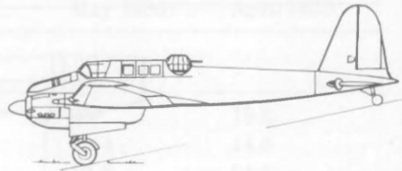
Tactical application:	single-seat fighter, aerial combat, day and night
Number of engines:	1
Crew:	1 pilot
Armament; either:	2 fixed machine-guns, 1,000 rounds per barrel
or:	1 fixed machine-cannon (20 mm), 200 rounds
Safety and rescue apparatus:	High-altitude oxygen apparatus
Maximum speed:	400 km/h at 6,000 m
Range/duration:	1½ hours at full throttle at 6,000 m
Climb rate:	6 km in 7 minutes
Working altitude range:	up to 9,000 m
Service ceiling:	10,000 m
Airfield size:	400 × 400 m
(normal German day)	Approach distance at up to 20 m altitude: 400 m

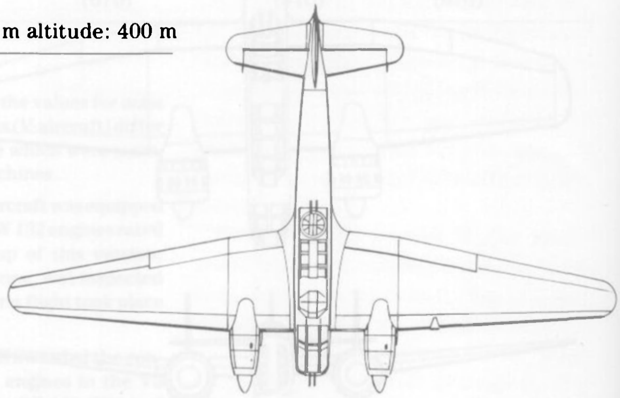
Tactical operations are to be undertaken by separate formations for day and night flying. It must be possible to install appropriate equipment for night flying.
Measures to reduce noise and prevent flames from the exhaust are also required for the night-fighter application.
Optimum pilot visibility for aerial combat.
Any average pilot must be able to master the aircraft.
The aircraft must be able to maintain maximum speed at working altitude for several periods of up to 20 minutes.
The aircraft must be capable of withstanding a dive at terminal velocity.
If the aircraft is capable of a spin at all, it must be easily possible to recover from it.

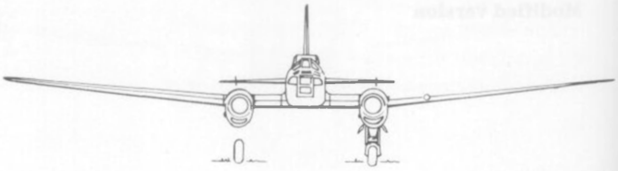
Performance of the aircraft is to be assessed in the following order of importance:

1. Horizontal flying speed
2. Rate of climb
3. Manoeuvrability

Capability for squadron take-off and landing (up to nine aircraft) is required.







Focke-Wulf Fw 57

The performance requirements for the single-seater were hardly any more exacting than for the destroyer; in fact the larger machine was required to have a 50 km/h higher maximum speed in its reconnaissance role. It almost looks as if the intention was to use the multi-seat destroyer as the basis for obtaining air supremacy, rather than the single-seat fighter.

An interesting feature of the new fighter requirements is that the order of importance in assessing the aircraft's performance was now:

1. Level flying speed,
2. Rate of climb,
3. Manoeuvrability.

One year earlier the order had been:

1. Rate of climb,
2. Manoeuvrability,
3. Level flying speed.

At that time the term commonly used for the fighter was the interceptor, whereas now it was known as the V.J. (Verfolgungsjager — pursuit fighter). The armament requirement had also been altered. Instead of the five hundred rounds per barrel, the demand was for one thousand rounds, with two fixed machine-guns. In compensation, the bomb-release capability was abandoned. And where the requirement had read: 'optimum visibility for aerial combat and low-level flight', it now ran: 'optimum visibility for aerial combat'.

In December 1933 the Technical Office LC II was given the task of undertaking the development of the new fighter: the pursuit fighter. In February 1934 three firms — Arado, Heinkel, and the Bayerische Flugzeugwerke — were awarded development contracts.

Inspection of the Arado 80 mock-up took place in July 1934, followed by the Heinkel He 112 and the Messerschmitt Bf 109 in October 1934. My superior at the time was director of the German Experimental Aviation Institute at the Luftwaffe testing station at Rechlin. He was present at a meeting with the Secretary of State (Milch), during which the companies were awarded contracts to build three prototypes each. After the meeting he told me: 'New fighter aircraft are to be built; that was decided yesterday by the Secretary of State. Cantilever low-wing monoplanes, all with retractable undercarriages. Heinkel, Arado and Messerschmitt have been granted contracts. Heinkel and Arado may not build above 100 kg/sq m wing loading, Messerschmitt can go up to 125. The Secretary of State was not keen on going along with Messerschmitt, but in the end he gave in. Nothing much will come of it, he said, but as a pike in the carp pool Messerschmitt may be quite good.' With the benefit of hindsight, we all know what came of it.

In addition to these three companies there was a fourth member of the club — the firm of Focke-Wulf. Every single book on the subject claims that the company was granted its contract at the same time as Arado, Heinkel and BFW, but in fact it was not awarded until seven months later, in September 1934. The task of developing a high-wing pursuit fighter had not been entrusted to LC II until August. Unlike the others, Focke-Wulf designed a strut-braced high-wing monoplane, somewhat similar to the Home Defence Fw 56 in design, but with retractable undercarriage and built largely of metal. As the drag of such a configuration is inevitably higher, the motivation for this development remains unclear.

Cantilever Monoplanes Abroad

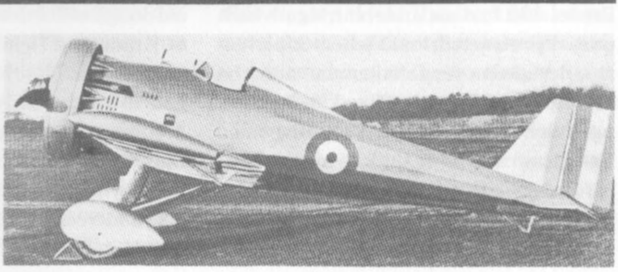
The leap from the braced biplane with fixed undercarriage to the cantilever low-wing monoplane with retractable undercarriage was not based on an arbitrary decision. It is not the case that the German aircraft designers went their own way in sweeping away the 'old rubbish'. For several years experiments with cantilever low-wing fighter aircraft had been under way abroad, where funds for experiments were available. In 1932 France had produced the Dewoitine D.500, while in

Dewoitine D.500, 1932

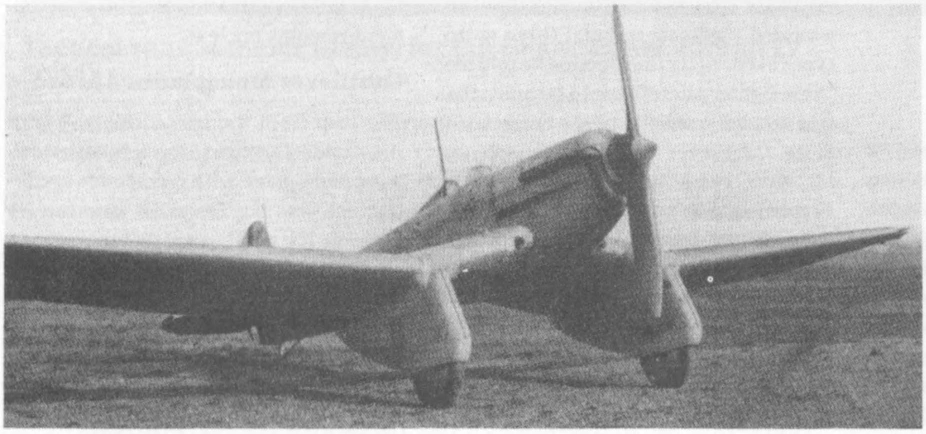
Wingspan	12.1 m
Length	7.7 m
Wing area	16.5 sq m
All-up weight	1,700 kg
Hispano-Suiza	700 hp

Vickers Jockey with 1931 modifications

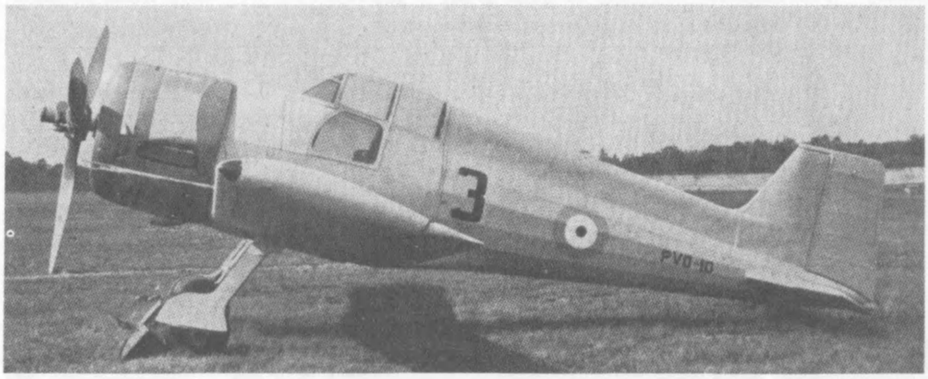
Wingspan	10 m
Length	7 m
Wing area	13.9 sq m
All-up weight	1,490 kg
Bristol Mercury	530 hp



Bristol 133, 1934. Engine: 640 hp Bristol Mercury. Undercarriage: semi-retractable to the rear.



Vickers-Supermarine F.7/30 Type 224, 1934. Engine: 600 hp Rolls-Royce Goshawk, intended for evaporative cooling. Undercarriage: non-retractable with trouser fairings. Wingspan 14 m.



Vickers F.5/34 Venom, 1936. Successor to the Jockey, with inward-retracting undercarriage.

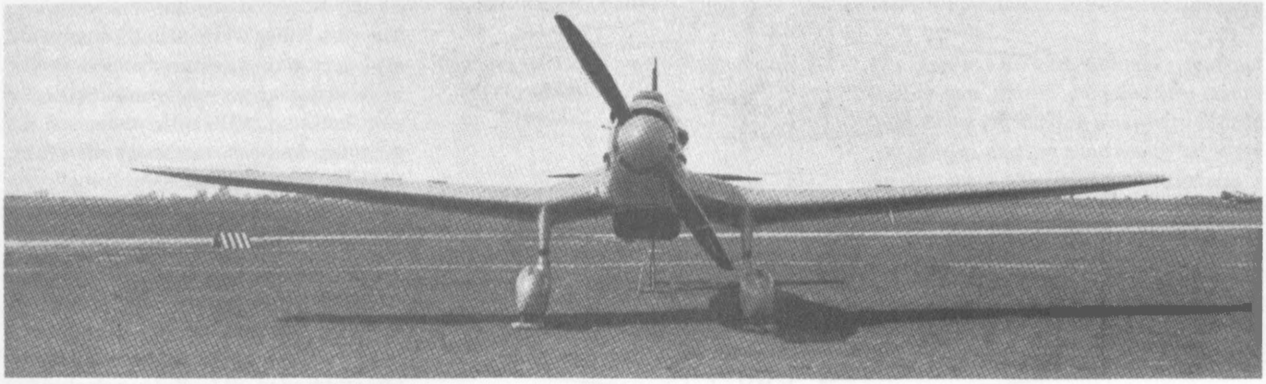
Britain slightly earlier Vickers had built the Jockey; both of them with a fixed undercarriage, but the Jockey already had a wing loading above 100 kg/sq m. The Bristol 133 had an undercarriage which partially retracted, and Vickers Supermarine designed a very similar machine, the F.7/30 Type 224 with a fixed undercarriage faired by 'trousers'. The last-named British aircraft were built to meet a 1931 official specification.

The German Prototypes

In Germany, as has already been mentioned, a fighter along these lines had been in the offing ever since the He 70. From old design office documents from the firms of Arado and Heinkel, long since disappeared alas, I know that both companies had, in 1932 or early 1933, submitted suggestions concerning cantilever low-wing fighter aircraft. Of the Heinkel project I know with certainty that it had a retractable undercarriage. It is also safe to assume that Messerschmitt had been working on similar projects, and had made approaches to the Office. Two factors point to this: first, the participation of BFW in the development of the single-seat fighter is difficult to explain in any other way; second, the aircraft was completed so early.

Much time had been wasted since these designs had been drawn up, and now a new fighter had to be produced at top speed. In many respects the Bayerische Flugzeugwerke was in a better position to do this than Arado and Heinkel. BFW was

Arado Ar 80 with Rolls-Royce Kestrel engine.



Arado Ar 80.

considered by the Ministry as the outsider in the group, and felt free to diverge from the requirements, while Heinkel and Arado were constrained to stick rigidly to the requirements (and many sub-requirements), since it was from one of these sources that the new fighter was eventually expected to come. A further advantage held by Messerschmitt was that it was the only company with substantial experience in sheet metal construction in general, and flat sheet fabrication in particular. It is likely that Heinkel had been working on the all-metal He 111 for a year, but its predecessor, the He 70, still had a wooden wing, even if the fuselage was fabricated in smooth dural sheet. Arado had absolutely no experience in this type of metal construction, but had brought the welded steel-tube structure to a high level of sophistication. Walter Rethel, for many years Arado's chief designer, was capable of taking the torch out of the hands of the best welders in his factory, and show them how to weld a difficult piece. He moved to BFW at the end of 1938.

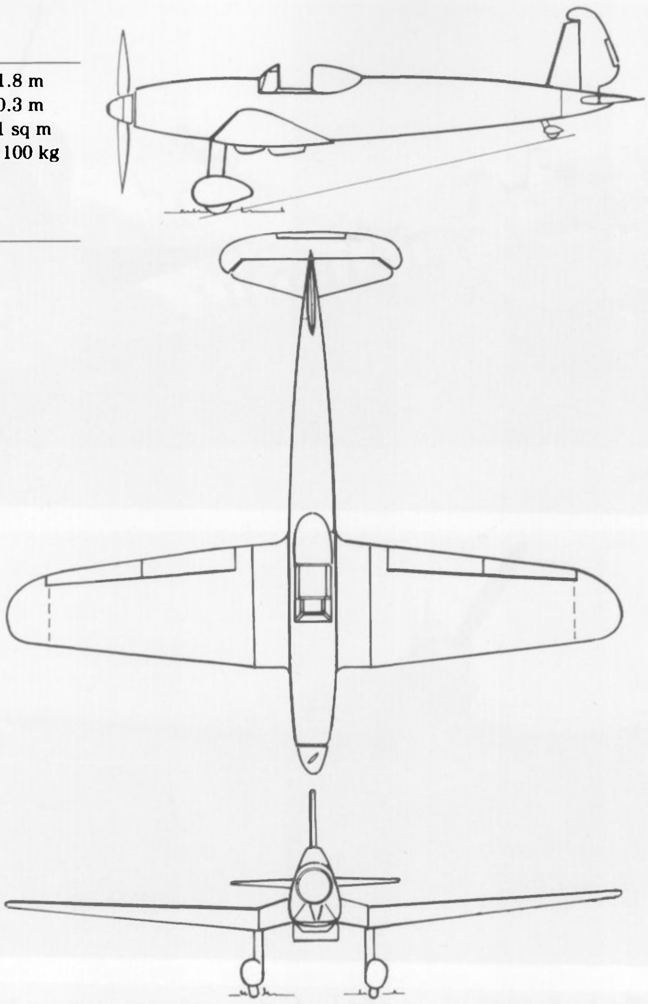
The Arado 80. For the new fighter Arado was specifically required to build the forward section of the fuselage in steel tube with removable sheet aluminium cowling. The purpose of this was twofold: to ensure ease of access and maintenance to all equipment, including the fuel tanks and weapons, and also to make the machine easy to work on with the facilities available at the Front. In fact, this requirement did not involve a substantial deviation from the techniques used on aircraft fabricated from all flat sheet. In the latter case the fuselage nose section, housing the engine, was already a framework with removable sheet metal skinning. Moreover the latest British monoplanes of the period had fuselage built entirely out of steel tubing, some of them even fabric-covered at the tail end. In any case, it is certain that Arado did not object strongly to the Office's demand for a steel-tube centre section. If a pressure cabin for the pilot had been a possibility, then the idea would certainly have been abandoned. But the Office had no such ambitions, even though flight altitudes of up to 10,000 m were under consideration. In an emergency this was still possible with oxygen.

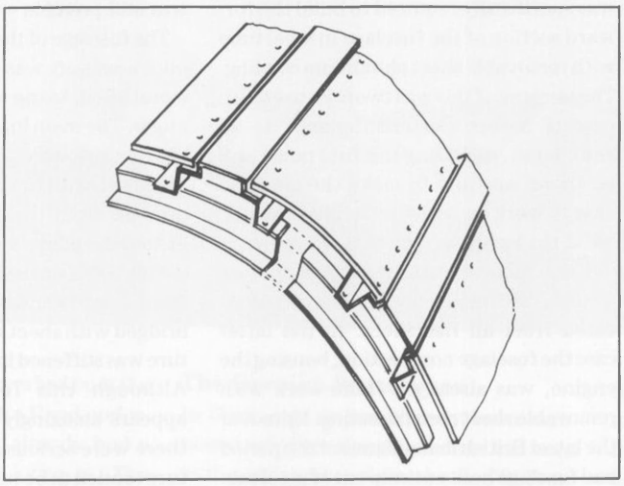
The fuselage of the Arado Ar 80 from the pilot's seat aft was constructed as an all-metal shell, using an entirely new technique. The main load-bearing elements of the fuselage were profile stringers, spaced evenly around the circumference, which tapered from the connecting bulkhead behind the pilot's seat back to the tail. The spaces between the stringers — wide at the front, narrower towards the tail — were bridged with sheet aluminium. The structure was stiffened internally with formers. Although this form of construction appears amazingly simple at first sight, there were serious drawbacks: the structure tended to be heavy, as it was not possible to step down the thickness of the metal sheet, and the structure was expensive to produce, as the number of rivets was high.

The cantilever tail surfaces and aerodynamically balanced control surfaces were designed in what was now already known as the Arado style, with the fin set forward of the tailplane. To avoid the complication

Arado Ar 80

Wingspan	11.8 m
Length	10.3 m
Wing area	21 sq m
All-up weight	2,100 kg
Rolls-Royce Kestrel/Junkers-Jumo 210	





Arado Ar 80 fuselage construction.

of a tailplane incidence adjustment mechanism, the fuselage was very long, and in consequence the pilot's seat was situated a long way forward to maintain the correct centre of gravity. Incidentally, the Office insisted that the cockpit should be open. The fuselage centre section, to which the metal shell tail end at the rear and the removable engine mounting at the front were attached, was built in a single piece as a steel-tube assembly incorporating the stub wings. The outer wing panels, which were attached to the stub wings, were two-spar structures built in smooth metal sheet. Wing flaps and ailerons were still fabric-covered, as were the rudder and elevator. There were large apertures in the underside of the wing skin to allow access during manufacture and maintenance. The stub wings were inclined downward slightly, *i.e.* they featured anhedral. The main undercarriage was to retract to the rear, rotating at the same time, and the downward projection allowed the wheels to lie just aft of the rear spar. Initially the retraction mechanism was to have been driven by the engine of a compressed air drill and worm gears, but later an electrically-powered version was to be tried. The spring strut, which lay below the wing parallel with the fuselage centreline after retraction, swivelled in a sleeve, and the rather awkward design of this assembly caused the mechanism to jam. Much valuable time was wasted in attempts to make the original design function correctly, but eventually it became necessary to develop an altogether new retracting mechanism. However, building a new undercarriage takes almost as long as an entire aircraft. If the machine was not to be hopelessly late for comparative flight testing, which had originally been planned for the end of 1935 and subsequently postponed to the beginning of 1936, a temporary solution had to be found. A fixed undercarriage was installed, legs and wheels were fitted with streamlined fairings and spats, and the machine was sent for flight testing. It is widely believed that the Ar 80 was designed from the outset with a fixed undercarriage, but that is not the case.

The aircraft proved to be easy and pleasant to fly. The roll rate left something to be desired, because of the rather small ailerons, and the machine's fixed undercarriage made it noticeably slower than the competition. Although it offered safe and completely docile flying characteristics, the machine could not be considered

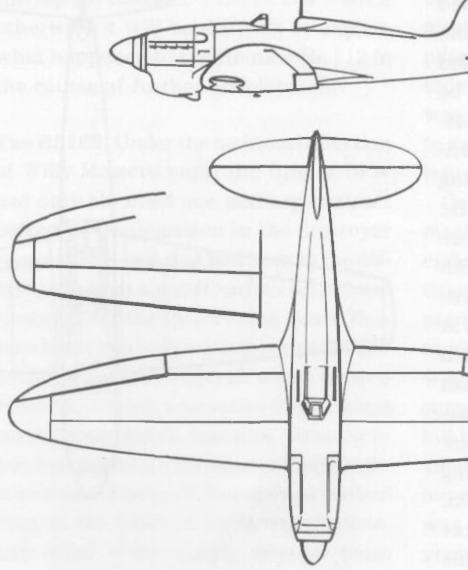
a very successful design. It was also plagued with teething troubles. For example, on one occasion the sheet aluminium skin on the upper surface of one stub wing came loose at the front spar, and fluttered about behind the rear spar like a flag. Instead of investigating the problem and changing the design, engineers simply fitted a new skin; the test pilot left the company in protest, and this did little to accelerate the pace of development.

Arado soon realised that the Ar 80 had no hope against the competition and threw in the towel. Despite the fact that the aircraft was fundamentally sound in terms of size and configuration, the company made no effort to revive its fortunes by revising the design. The third test aircraft was not even completed; instead the components already made were incorporated into a test aircraft which was used to test high-lift aids, safety control systems and other equipment. Arado wanted to be able to install very large landing flaps — Fowler flaps — in the test aircraft, extending right up to the fuselage, and to this end the anhedral stub wings were replaced by a straight dihedral arrangement. The spring struts for the undercarriage were simply extended to make up for lost height; a retractable undercarriage was not needed for an experimental aircraft. A second seat was installed to accommodate an observer for taking measurements; this is the foundation of the fable about a two-seat Arado fighter.

The experience which Arado obtained with the test aircraft had no great influence on the company's subsequent aircraft developments.

Heinkel He 112 V1 with Rolls-Royce Kestrel engine.

Heinkel He 112	V1	V2
Wingspan	12.6 m	11.5 m
Length	8.9 m	8.9 m
Wing area	23.2 sq ft	21.6 sq m
Structural weight	2,200 kg	
Rolls-RoyceKestrel/ Junkers-Jumo 210		



Inset left: the reduced-span wing

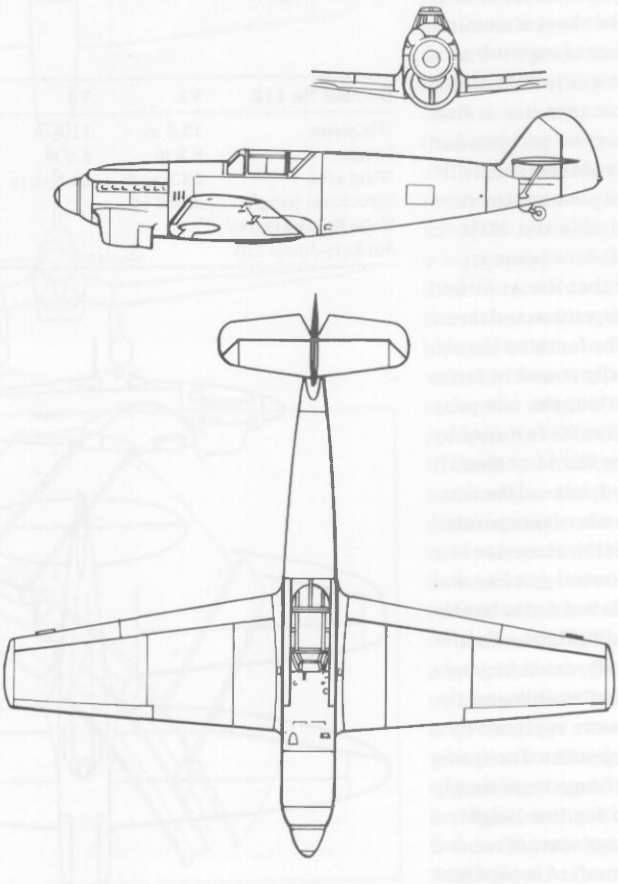
The Heinkel He 112. Heinkel's contract for the new fighter included two conditions: the wing loading was not to exceed 100 kg/sq m, and the wing was to have two double spars, designed to withstand a g-load of around eight, *i.e.* if part of one double spar was damaged, the other half could withstand a g-load of four. The Ministry could still not bring itself to consider the idea of a true load-bearing wing skin, or stressed skin, for a fighter aircraft.

A third condition was set by the company itself: the aircraft had to look similar to the He 70, *i.e.* it was to have an elliptical wing, along with a rounded fuselage. In so doing Heinkel had ensured that constructing the aircraft would be unnecessarily difficult. The wing skins were made without the complex jigs which were really necessary, and when fixed to the wings the surface looked decidedly wavy. Machining the curved spars whilst keeping to the necessary dimensions was difficult, with the result that the wing section showed steps at the front and rear spar locations. It would have been possible to overcome all these problems if sufficient time and effort had been invested in jigs, stretch-forming presses and the like, but such measures were rather expensive for three test aircraft, and anyway there was no time, or it was thought that there was no time. The Office made things worse by demanding everything immediately if not yesterday. The contractors were also guilty of idly promising to meet short deadlines.

The new He 112 fighter shared the essential external characteristics of the He 70. It was a low-winger whose wings were inclined slightly downward from the fuselage, then bent up at the necessary dihedral angle over the outboard panels. This layout was adopted because Heinkel wanted the wings to project at right-angles from the fuselage, which was of rounded cross-section. The underside of the fuselage was very much more rounded than that of the He 70, which had to be more bulbous below to accommodate passengers' feet. Because of this, the downward inclination, or anhedral, of the wing roots was very much steeper on the He 112, which resulted in turn in a more pronounced 'elbow' at the junction with the outboard panels. The outward-retracting undercarriage was attached at the lowest point of the wings, resulting in a comfortably wide track of more than three metres. The wing spars were massive components, and provided a secure foundation for the undercarriage spring struts and hydraulic retraction struts, which doubled as undercarriage support struts in the 'down' position. The double spar wing design, although rather heavy, made it possible to build the wing in three separate sections — front, centre section and trailing edge — and bolt them together after completion, which offered advantages for manufacture and repair. Simple camber-changing flaps were fitted, but they could not be extended right up to the fuselage because of the 'elbow' in the wing. The generously proportioned ailerons featured internal mass balances.

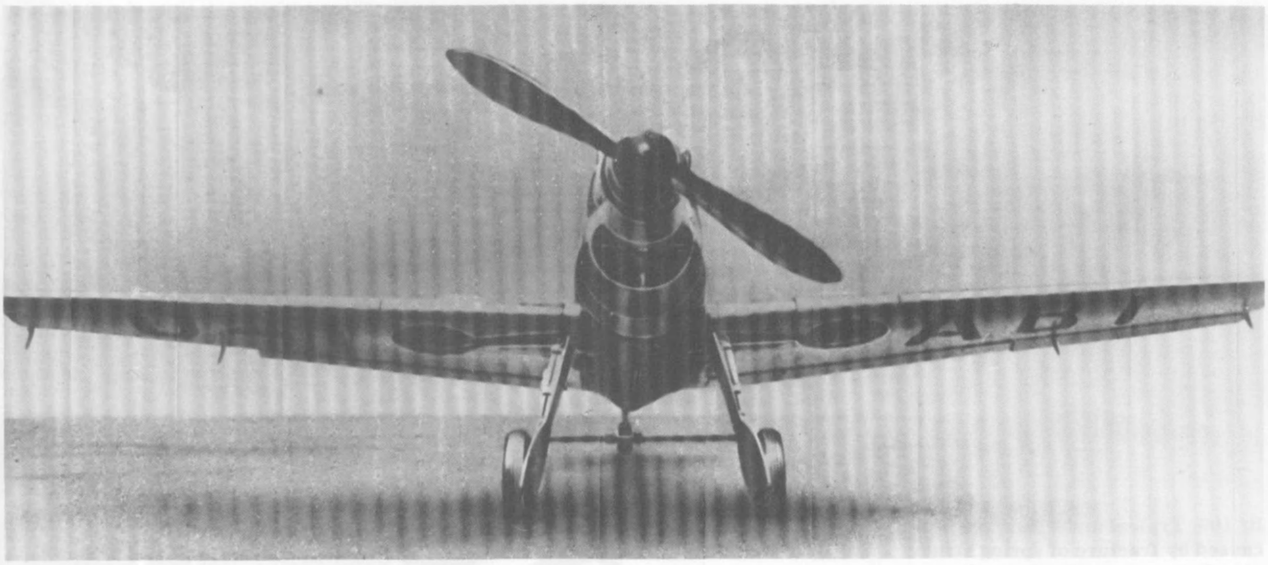
The fuselage was a true monocoque structure, consisting of a load-bearing skin stiffened with annular formers and profiled stringers. The cross-section was rounded, becoming roughly circular at the tail end. The cantilever tail surfaces were mounted in a low-drag arrangement, both at approximately the same station when viewed from the side. The tailwheel could be retracted hydraulically into the tail cone behind the tailplane bulkhead. The cockpit was open, in accordance with the Office's wishes, but from the start rails were fitted to the top of the fuselage, so that a rearward sliding glazed canopy could be fitted. The front part of the fuselage featured a series of five bulges, all carefully faired in; two housed the lateral machine-guns, mounted fairly far aft so that the pilot could reach them; two more formed fairings for the exhaust — in consideration of the requirements for flame damping — and the fifth formed the air inlet. The whole arrangement reflected the thought and care which had gone into the design. Unfortunately the propeller produced an angled airflow along the fuselage, and since these bulges were designed for a straight airflow, drag was higher than expected.

The radiator installation in the round fuselage was rather awkward. It was fitted below the engine, offset slightly to the rear, and looked as if it had been grafted on afterwards, instead of being an integral



BFW Bf 109 V1

Wingspan	10.0 m
Length	8.6 m
Wing area	16.3 sq m
Structural weight	2,000 kg
Rolls-Royce Kestrel/ Junkers-Jumo 210D	



part of the aircraft. This is understandable, since the Junkers engine for which the first test aircraft was built was not available in time, and the machine had to be fitted with the British Rolls-Royce Kestrel. But it seems that in any case Heinkel intended using a surface cooling system instead of the normal block radiator with evaporative cooling; a technique that had been tried on the first aircraft in Britain to carry the name Spitfire[12].

A memorandum from the Technical Office (LC II) includes the following entry:

'5 November 1934 — Heinkel requires a Rolls-Royce Kestrel for the He 112 V1, a Jumo 10 with water cooling for the V2, and a Jumo 10 with evaporative cooling for the 112 V3.'

This may well have seemed to Junkers and the Office too risky a venture for the new engine. No aircraft was built with evaporative cooling, but the awkward radiator installation was retained, producing rather high drag[13], because the designers still harboured a secret hope of fitting evaporative cooling.

The wing area of 23.2 sq m was generous compared with its competitors, and because the wheels retracted outward, the wing also had to be comparatively thick. This, combined with the rather awkward radiator installation, the uneven wing surfaces and the capacious fuselage, kept the maximum speed down below what was expected, although it still comfortably exceeded the performance requirements. The first flight took place in September 1935, eighteen months after the contract had been awarded, and not quite one year after the mock-up had been inspected.

The aircraft's external appearance inspired confidence, and gave an impression of solidity, and this impression was reinforced at close range. It looked slightly squat, very slightly clumsy. Right from the start its take-off and landing qualities were satisfactory. It was judged to be acceptable by test centre pilots flying it at the company's airfield, and was delivered to the Rechlin test centre in December 1935.

Before we cover further development of the Heinkel He 112 in detail, we need to consider the third contender for the pursuit fighter contract — the Bf 109 — since otherwise it will be difficult to explain what happened to the Heinkel He 112 in the course of further development.

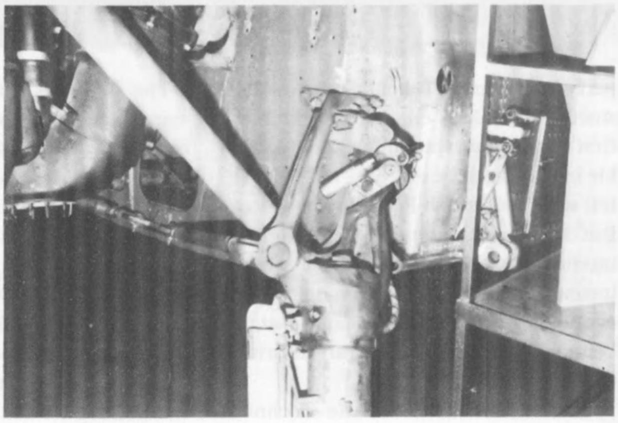
The Bf 109. Under the technical direction of Willy Messerschmitt the firm of BFW had only obtained one military contract before its participation in the destroyer competition, and that had been in the distant past. That aircraft had been a failure. However, in the intervening years Messerschmitt had built a whole series of high-performance sports aircraft which showed evidence of clear, innovative thinking and many clever detail features. Messerschmitt had gained a reputation: he built high-performance aircraft, but always worked close to the limits of what was possible, and often went slightly beyond those limits. It is no longer possible to establish who it was that influenced the decision to make BFW the third company to be granted a pursuit fighter contract, and on what grounds the firm was set alongside the traditional fighter firms of Heinkel and Arado: perhaps it was the result of convincing preliminary work. Other books frequently claim that the real reason was the BFW Me 108 — that was its original designation — which was built for the 1934 round-Europe flight, but the claim does not bear close examination. First, the fighter contract was granted in February 1934, four months before the BFW Me 108 first flew on 13 June. Secondly the 108 proved to be completely unacceptable in terms of flying characteristics, as a result of the adoption of spoilers as the sole means of lateral control. When one of the pilots selected for the competition was killed in a low-speed training session, it was no longer possible for Messerschmitt to avoid modifying the lateral control system of the BFW Me 108.

Contracts for the round-Europe machines had been very late, and only eight weeks remained before the competition; this was not long enough to find a permanent solution to the problem. Small auxiliary ailerons right at the wingtips were all that could be added, and it is not surprising that the Me 108 was anything but brilliant at low speed, and one of the aims of the competition had been to improve low-speed handling. The aircraft was subsequently fitted with new, conventional ailerons, and became very popular. So much incorrect information has been written on this subject that it was thought a full explanation could be justified.

Experience gained in designing and testing the BFW Me 108 must surely have accelerated the work on the Bf 109 fighter. Many fundamental problems, such as

BFW Bf 109 V1.

Bf 109. Typical undercarriage failure caused by fracture of spring strut attachment at the fuselage after a ground loop; a continual occurrence.



Bf 109. Undercarriage attachment on the fuselage.

accommodating the undercarriage in front of the wing mainspar, transferring flight loads around the wheel well in the swing, the tail surface arrangement and much more, had already been considered, and solutions found. The Me 108 could almost be seen as a prototype for the Bf 109, or perhaps it would be more accurate to say that the 109 was the Me 108 concept adapted to fit the mould of a fighter.

The Bf 109, designed under the direction of Willy Messerschmitt, was the lightest and smallest of the competitors for the pursuit-fighter contract, and naturally had the best climb performance and highest top speed, in spite of the many aerodynamic sins which had been committed in the pursuit of minimum weight. Nevertheless it is difficult to understand why the tailplane was strut braced, while the wing was a cantilever design; why the aileron mass balances were allowed to hang out in the breeze, while the wing had been kept as thin and smooth as possible; why the tailwheel was not retractable, even though the main undercarriage was. All these things were destined to be put right during the long life of the Bf 109. At the time, however, the aircraft offered the lowest overall drag by a wide margin, not least because of its excellent radiator installation. Like the others, the first test aircraft was equipped with the Rolls-Royce Kestrel engine, as the Junkers-Jumo 210, for which the aircraft was designed, was not yet ready.

Testing the New Types

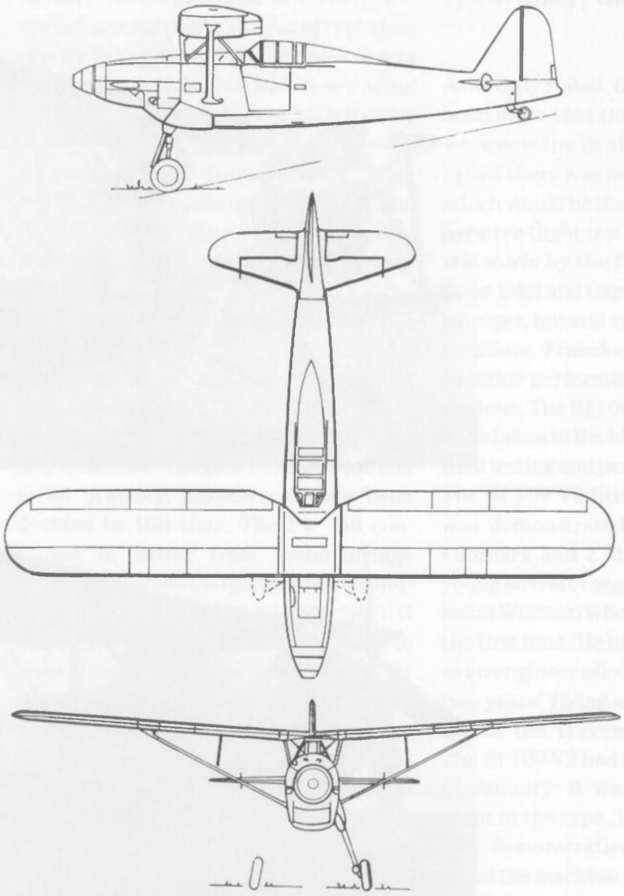
In May 1935 the Bf 109 took to the air for the first time: on time, and several months before its competitors, although there was a temporary connecting strut between the fixed spring struts of the cantilever undercarriage. Something or other was not quite right. The child seemed to be a little rickety. After four or five months' testing at the factory, the machine was far enough advanced for testing at Rechlin. Although slightly behind schedule the Bf 109 was still in front of the competition, and represented the first of the new class of fighter, for which Rechlin was waiting impatiently. On a sunny autumn day the aircraft arrived at Rechlin, after an interim stop at Juterbog. The pilot unloaded baggage and tools and took off for the demonstration flight, which was to precede the transfer. After an impressive aerobatic demonstration he landed, but the aircraft made an involuntary ground-loop (a sudden horizontal rotation after touch-down) which broke one undercarriage leg; the 109 came to a halt tail-high, perched on one healthy leg, the nose, and one wingtip. Pilots at the test centre, who had assembled at the airfield to witness the demonstration flight, were heard to agree that the landing was a 'perfect three-pointer'. Everyone returned to the day's duties. None of them knew that they had witnessed the manifestation of a design fault which the aircraft never managed to shed. Naturally the blame for the accident fell on the pilot. After all, there could be nothing wrong with the aircraft. The accident on landing at Rechlin and the unplanned landing at Juterbog, where Luftwaffe personnel were able to see the new 'secret' aircraft, created a huge fuss. The Messerschmitt company, instead of locating and correcting the basically unsound undercarriage attachment, dismissed the test pilot.

A few weeks later the damage had been

Focke-Wulf FW 159.

repaired and flight operations were resumed. In the meantime the Arado Ar 80 had also been made ready for testing, after work on correcting the undercarriage problems had been halted, and a non-retractable undercarriage installed. In September the He 112 made its maiden flight, and in December it was transferred to Travemünde, the naval test centre, where the fighter testing process was to take place. The new seaplanes had not arrived, and Travemünde was therefore not overworked, whereas flying was continuing day and night at Rechlin. The strain on the flying personnel there was severe, but most of them were young men between 20 and 30, and they enjoyed it. Everyone had to fly for at least one hour fifteen minutes every day, regardless of how much administrative and office work he had to do. When long-term testing and S-testing were under way, the load was usually much heavier. After a normal working day pilots frequently had to fly the twelve hundred kilometres to Munich and back in order to obtain engine spares, arriving back in Rechlin towards midnight. One pilot attempted to log 100 flying hours in seven days, and a different pair of airmen made one hundred landings on a single Sunday afternoon as part of a brake-testing programme.

The Fw 159. People in the aircraft industry were working equally hard. The firm of Focke-Wulf, which had only received a pursuit-fighter contract in September 1934, attempted to make up lost ground in a spectacular effort. The mock-up was



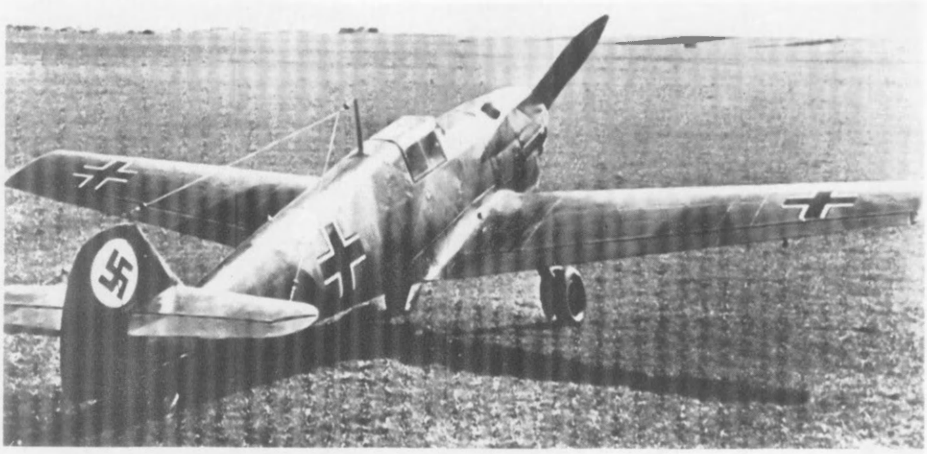
Focke-Wulf Fw 159

Wingspan	12.4 m
Length	10.0 m
Wing area	20.2 sq m
Empty weight	1,875 kg
All-up weight	2,250 kg
Junkers-Jumo 210	

BFW Bf 109; a prototype in the air.

Heinkel dive-bombers He 50A and B.

BFW Bf 109B.



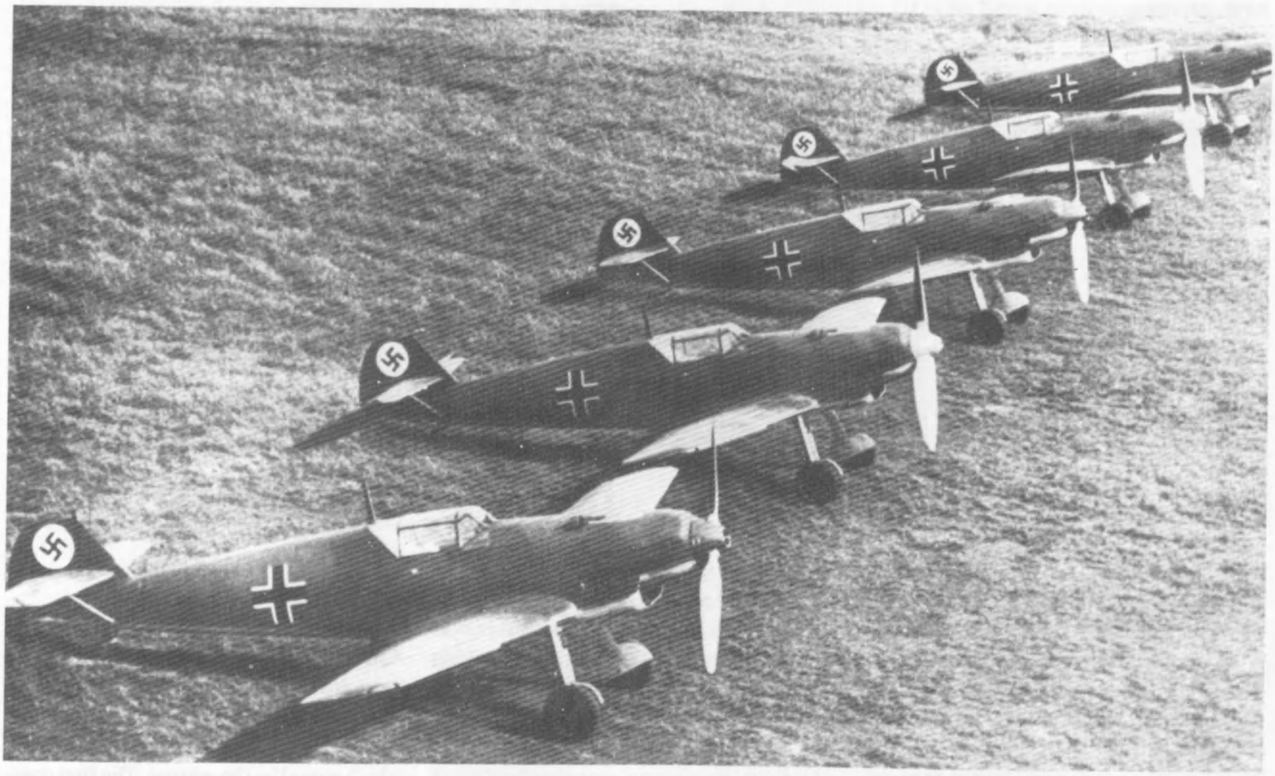
inspected in June 1935, and the first prototype was ready for flight in November — not six months later. It too was equipped with the Rolls-Royce Kestrel engine. The 12.4 m span all-metal wing featured constant chord and was braced to the underside of the fuselage with a single strut. The attachment of the wing centre section, known as the cabane in the First World War, followed the style of that period exactly, with two N-struts and diagonal bracing wires. Like the Arado Ar 80, the Fw 159 had a steel-tube framework fuselage at the nose, covered by removable sheet panels, to ensure unobstructed access. The rear section, aft of the pilot's seat, was a monocoque structure, carrying the cantilever tail surfaces at the end, again like the Ar 80. The tail arrangement of the Fw 159 was quite different, however, with the tailplane mounted forward of much of the fin. Only a vanishingly small part of the vertical stabiliser was visible from below the tailplane. The undercarriage consisted of two cantilever spring struts, which folded up and retracted into the front part of the fuselage. The pilot's cockpit was covered by a glazed canopy which could be slid back on rails.

In the haste to complete the machine on time, many aspects of the design were given insufficient attention. The power of the oil cylinders which were to extend the undercarriage was not sufficient to overcome the pressure of the air, which tended to push the undercarrige back against the direction of the extension. This problem became apparent on the very first flight: when the undercarriage was extended only one leg appeared, which then retracted while the other came out. The aircraft appeared to be kicking out with its legs. There was no option but to fly the aircraft around until it ran out of fuel, then make a belly landing. This procedure was usually quite harmless with a low-wing monoplane, but was a risky undertaking with a high-wing type, because there was no damping effect from the wing. After this initial failure new undercarriage parts of increased strength had to be made, and the aircraft repaired. It did not appear again at the test centre until March, *i.e.* the date originally planned for the first flight at the manufacturer's airfield. The company could have saved much money and effort had it not tried so desperately to beat the deadline. It was all an unnecessary waste, for the fighter competition had to all practical purposes already been decided by this time. The Fw 159 continued to suffer from undercarriage problems. The second prototype continually broke its legs, but again and again it was repaired, and the firm continued to push with all its vigour to find a slot for the aircraft in the armament programme. It was initially included in the lists of the LC II under the classification pursuit fighter, but in July 1936 its classification was changed to Front fighter. In April 1937 it then reappeared in the lists under the designation Fw 259, this time fitted with the Daimler-Benz DB 601 engine, but a laconic note was appended: 'zero-series will not be built, as the aircraft is no longer of interest for procurement.' The DB 601-powered version was never built. It is difficult to understand why the company stuck with the Fw 159, the more so since in November 1935 it was awarded a contract to develop a twin-engined single-seat fighter — the Fw 187. But more of this later.

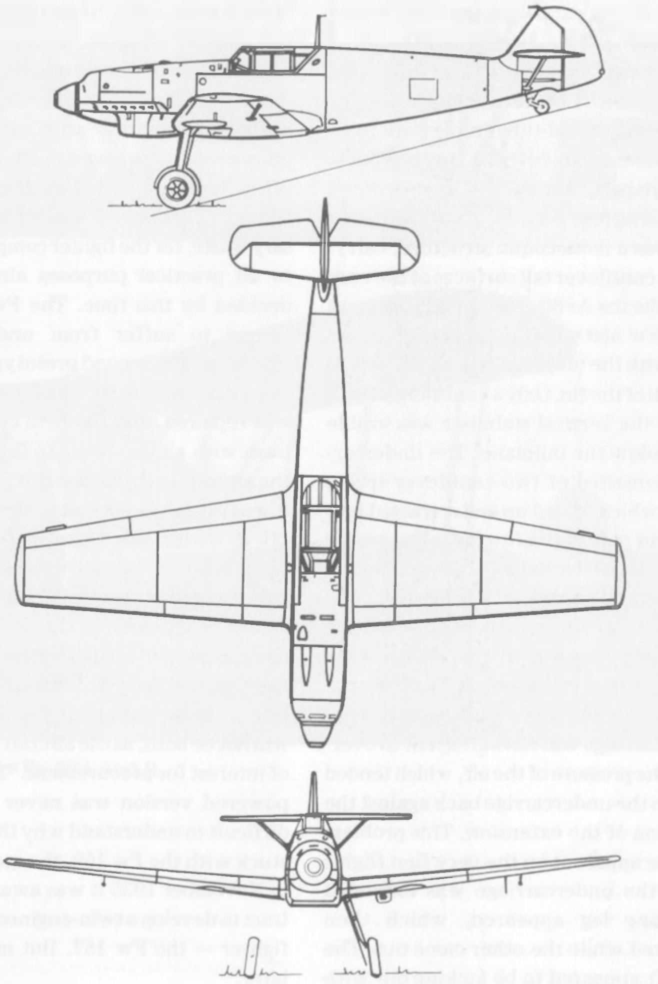
The Winner: the Bf 109

As already stated, the decision had already been made that the only two contenders were now the Bf 109 and the He 112, and in fact there was no longer any real doubt which would be the winner. The first comparative flight test of the pursuit fighters was made by the former Luftwaffe aces Ernst Udet and Captain von Greim and two younger, but still very experienced Rechlin pilots, Francke and Conrad, and the superior performance of the Bf 109 was obvious. The Bf 109 V2 and the He 112 V1 were taken to Rechlin in February 1936 for final testing and performance assessment. The Bf 109 V2 fitted with the Jumo 210 was demonstrated at Rechlin on 26/27 February and 2 March. The pilot was a young aircraft construction foreman Herrmann Wurster, who was flying for BFW for the first time. He had joined the company as an engineer pilot in January, after only two years' flying experience in the DVL and at the Travemünde testing station. The Bf 109 V2 had made its first flight on 21 January. It was only Wurster's 15th flight in the type, but he gave an impressive demonstration of the aircraft. He dived the machine from 7,000 m altitude, recovering close to the ground pulling 7.8 g, and made a spinning demonstration including 21 left and 17 right turns, followed by a perfect recovery. This demonstration could hardly have failed to impress the aircraft's customers.

His competitor in the He 112 V2, Gerhard Nitschke, who had several years' advantage in age and flying experience, was not so fortunate. During a spin to the left with maximum rearward centre of gravity —

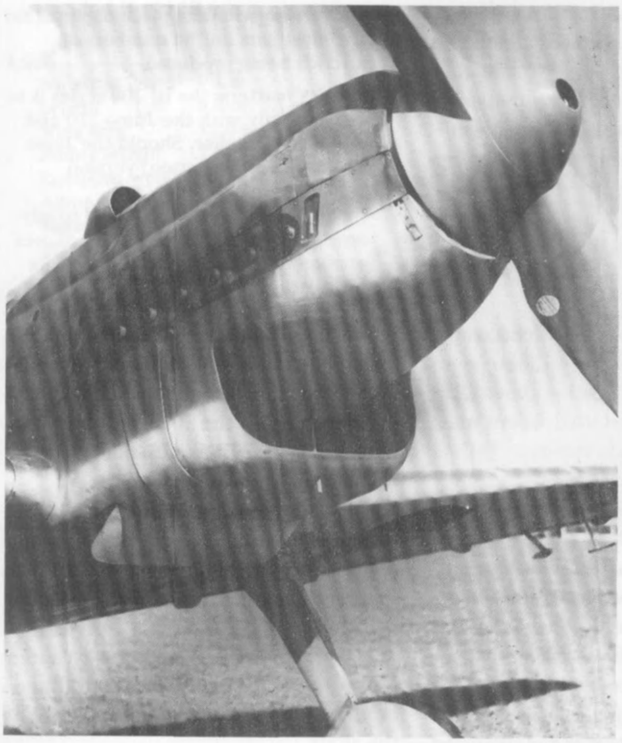


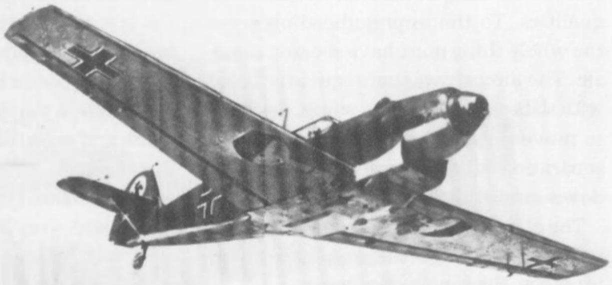
BFW Bf 109B, early series, 1937.



BFW Bf 109B

Wingspan	9.88 m
Length	8.55 m
Wing area	16.3 sq m
Empty weight	1,380 kg
Equipped weight	1,580 kg
All-up weight	1,955 kg
Junkers-Jumo 210 D	680 hp
Maximum speed	465 km/h at 4,000 m
Armament	Four MG17 machine-guns





BFW Bf 109B.

BFW Bf 109B. Jumo 210 engine and radiator installation.

the most difficult situation — the machine went into a flat spin, and it proved impossible to recover. The engine then stopped, and Nitschke had to bale out. The aircraft was a total loss. Incidentally the Bf 109 V2 was aiso lost five weeks later, when the front part of the canopy flew off soon after take-off, and the pilot, unable to see, had to put the aircraft down as best he could. The initial testing and the performance comparisons with the Rolls-Royce Kestrel were now at an end.

The Rechlin pilots set about testing and assessing the flying characteristics of the two competing aircraft without prejudice, in spite of the convincing demonstration they had witnessed. It turned out that appearances had been deceptive. An experienced tightrope walker may trip lightly across the high wire, but that does not mean it is a safe bridge for the average individual. It is just the same with aircraft and skilful pilots. Moreover an aircraft's aerobatic capability does not necessarily mean that it will be a good combat machine, especially with an ordinary pilot at the controls. The Bf 109 and He 112 were flown and tested against each other, and the general consensus was: the He 112 was more pleasant to fly, and above all had better landing characteristics. There follows an excerpt from a report by the official in charge, aircraft construction foreman Gerhard Geike:

'The two aircraft exhibit very different characteristics. I experienced my first surprise with the Bf 109 when I attempted a loop, a manoeuvre which must surely present no problem at all for a fighter aircraft. I tried to pull the aircraft round with full throttle and large elevator movement. When it reached the vertical position, it suddenly started to rotate around the longitudinal axis. It was spinning upwards. When I closed the throttle, it dropped one wing and went into a dive. I could only fly a perfect loop if I used small elevator movement, and the loop was kept to a large diameter. The cause of the problem was early airflow separation on the wings. This unpleasant characteristic manifested itself again if a three-point landing was attempted. It took great skill to land the aircraft on both wheels simultaneously. As the airflow separation did not occur simultaneously at both wingtips, the aircraft always stalled on one side just before touch-down, and the wheel on that side touched the ground first.

This phenomenon prompted me to investigate the aircraft's behaviour in a spin. I was in for a further surprise. After closing the throttle I pulled the stick back slowly. The aircraft stalled very quickly, and fell into a steep spin. During the second rotation the spin became flat. Thereafter the spin continued with steep rotations alternating with flat rotations. I had never before come across this phenomenon. Most aircraft will complete about eight to ten rotations in a steep spin, before gradually going into a flat spin. In most cases the only recourse from this situation is to bale out. However, I found it possible to recover the Bf 109 into a dive after ten to twelve turns of spin by pushing the stick fully forward. The aircraft's handling could be improved by altering the incidence of the outer wings.

The He 112, which lacked the enclosed cockpit of the Bf 109, had more pleasant flying characteristics. It had no tendency to early tip-stall.

Four weeks after the start of testing, on 24 March, 1936, the second prototype of the Bf 109, D-IILU, was made available, this machine being fitted with the 610 hp Jumo 210. It was immediately subjected to a series of endurance tests, being flown by a number of pilots. My particular interest was again the machine's flying characteristics. In the framework of the endurance testing I made repeated aerobatic flights and spinning tests, and was unable to determine any difference in behaviour when stalled. To our surprise, before testing was complete, the decision was taken in favour of the Bf 109. In spite of its faults, it had been given preference because of its better performance, lower weight, and cheaper construction.'

So much for the report by the test pilot and officer in charge of Rechlin. The impression we get is that the decision in favour of the Bf 109 seemed to him to be incorrect. The aircraft's behaviour around the longitudinal axis when stalled, and all the other aspects of flight which are influenced by such characteristics, did not please him in the slightest, especially in

view of the dangers associated with those qualities. To the unprejudiced observer the whole thing must have seemed a puzzle. The aircraft was subsequently fitted with slats on the outboard wings, designed to prevent early airflow separation, but separation still occurred before touchdown, and still on one side.

The official in charge of the testing took immense trouble to get to to root of the problem. His report continues:

'We continued intensive testing of the Bf 109 V1. I had wool threads stuck to the wings and made further spinning tests, in an attempt to discover the cause of the boundary layer separation. A cine camera was installed behind the pilot's seat, so that the transition from laminar to turbulent flow could be recorded at all points on the wing surface. I also had the automatic slats locked by steel bands and made further tests.'

All these efforts were aimed at sorting out a dangerous fault which was the root cause of many accidents and, together with the fragile undercarriage attachment, caused innumerable instances of landing damage. But the Bf 109 had been selected as the standard fighter aircraft for the German Luftwaffe, perhaps in the expectation that all these difficulties would be sorted out somehow or other.

One feature of the Bf 109 which may have contributed to its selection was the fact that the undercarriage was attached to the fuselage, *i.e.* with the wings removed it could stand on its own legs. This had always been considered a plus in the lightplane competitions of earlier years, and it may have been thought to be the best solution. It was also widely believed that a hard landing could result in wing damage if the undercarriage was attached to the wing, with the potential danger of subsequent wing fracture in flight. After all, it was only a few years earlier that an awkward, overweight and aerodynamically unsound undercarriage design had been forced on Heinkel's first dive-bomber — the He 50A — at the express demand of the Ministry. Much toing and froing went on before a sensible solution could be adopted (HE 50B).

Later discussions on fighter selection have often quoted the 'simpler' construction of the Bf 109 in comparison to the He 112. Whether this argument actually had any influence on the decision is not certain, for no documents concerning the reasons have survived. In the Third Reich decisions on aircraft procurement were made on the authoritarian *Führerprinzip*. But it is also likely that the Bf 109 would have been considered easier to make. In fact the opposite is true, for the separate wing panels, moving slats, adjustable tailplane and so on, together with Willy Messerschmitt's preference for separate sub-assemblies, meant that the component count was very high, hence any slight advantage gained from the straight lines soon vanished. Who knew anything about mass production anyway? German companies, from the car industry to Zeiss, were sending technicians abroad — above all to the United States — to learn about mass production. And what numbers were they aiming at? What sort of 'mass' were they to produce? Did anyone have a clear idea of the ultimate goal in the armament process? Did such a goal exist at this time?

However that may be, the Bf 109 had the superior performance; it was faster and climbed better, and then offered a better all-round performance, which was of the utmost importance for a fighter aircraft. It could take off in a shorter distance, and could also land shorter, even though most pilots made no use of this capability, as the machine's bad landing habits showed up at the large angles of attack necessary for a short landing. The Bf 109, in the form of the Bf 109B, became the standard fighter aircraft of the German Luftwaffe. In reality the decision had been made just a few days after the demonstration flights at Travemünde, in a discussion held on 12 March, 1936; this is proved in extant LC II/1 documents. Under the heading: 'Bf 109 priority procurement' the document runs (excerpts):

1. Production to continue until further notice with standard equipment of Jumo 210, 2 controlled MG 17 (machine-guns), 2-blade airscrew and Revi C/12A (reflector-type gun sight). The V3 aircraft is to be prepared as quickly as possible in this form, and is to be sent to Travemünde E-station (test centre) for flight testing on 1.4.36.
2. Top priority work is to continue on converting So I (the zero-series) to 3 MG 17 (machine-guns). The V2 aircraft is to be used for this work; it is at present at Tr'de for testing the MG C/30[14].
   Notification will not take place until the whole So I is fitted with 3 MG 17 and has passed the test procedure, so that the Bf 109 in series production can be converted.
3. The only extra version to be considered initially is that armed with 1 MG C/30 L. Whether and when this conversion will take place depends for the most part on the numbers of aircraft being produced.
4. Sundry matters: the Bf 109 series is to be built only with the Jumo 210 and 2-bladed propeller. Should the Jumo 210 Einspritz (injection) version become available later, no modifications will be required to any assemblies of the So I. We can expect an experimental BMW 116 Einspritz installation in August'

Exactly one year later, on 13 February, 1937, Udet reported to the commanders that it was desirable to keep to a liquid-cooled engine of the 20-1 class, the Jumo 210, and that the BMW 116 should be abandoned for this reason.

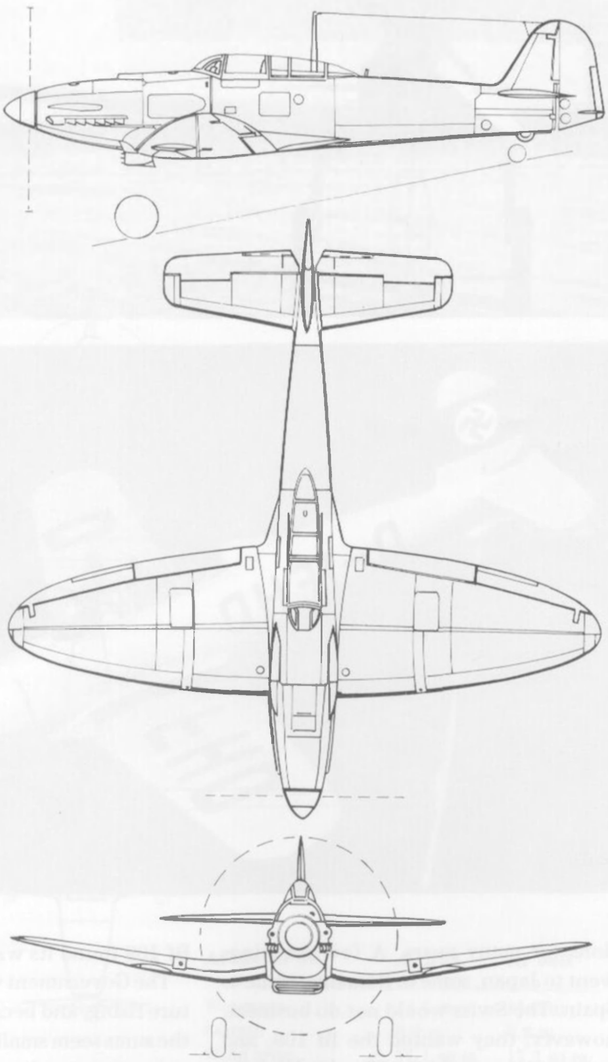
Air-cooled engines would also be developed instead of the expensive water-cooled units. In this connection it may be interesting to note that on 18 January, 1937, the LC II halted all work on weapons installation in engines, with the exception of the Jumo 210 C with a 20 mm cannon or an MG 17 machine-gun firing through the shaft.

Further Efforts at Heinkel

Heinkel could hardly believe it. The He 112, successor to the famous He 70, had been pushed into second place by the product of a firm with no experience in fighter aircraft production. In fact everyone at Heinkel had known for a long time that they were well behind the terms of performance, since news about the size, weight and flying performance of the Bf 109 had reached the factory. The only solution was to reduce the size of the He 112 and thereby reduce its weight. But how was this to be achieved within a few months, let alone a few weeks? The first and most obvious course was to cut a piece off the wing — to chop its ears off. But what would that achieve? The original 23.2 sq m had now been reduced to 22 sq m — five per cent less wing area, *i.e.* hardly two per cent of the total surface area — and a drag reduction of less than that figure. If more than just the wingtip was cut, then the ailerons became too short, and their effectiveness insufficient. There was nothing for it: a new wing had to be built. It was begun soon after the prototype's first flights, and was ready in spring 1936. It soon became clear that the Bf 109 still had a performance advantage, and the new wing was in any case far from ideal. In the original arrangement, the undercarriage was located fairly far outboard, and retracted outward, which dic-

Heinkel He 112B

Wingspan	9.1 m
Length	9.3 m
Wing area	17.0 sq m
Empty weight	1,620 kg
Equipped weight	1,850 kg
All-up weight	2,250 kg
Junkers-Jumo 210 D	680 hp
Armament	Two MG17 machine-guns, two MG FF machine guns



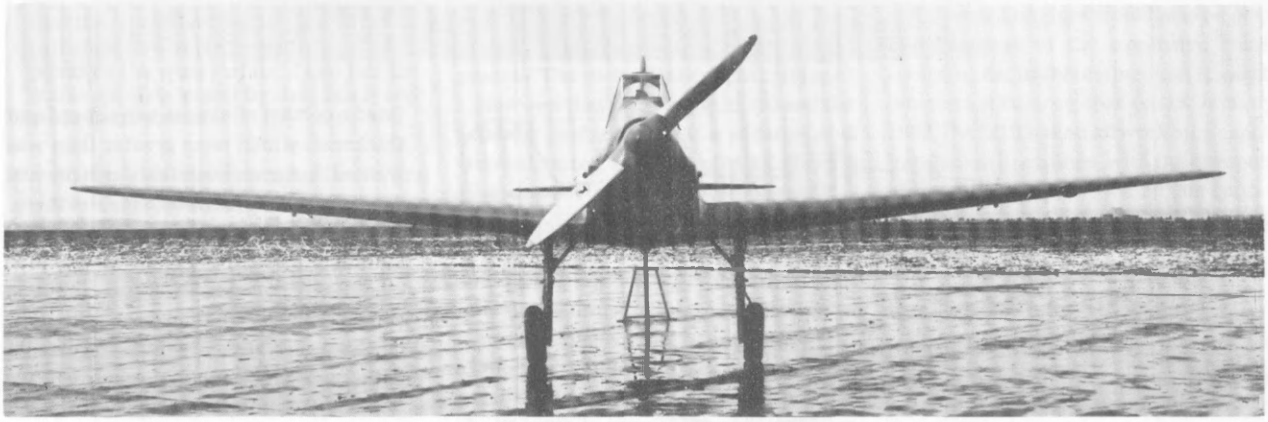
Heinkel He 112B

tated a certain minimum wing chord and thickness, which were greater than was wanted. In a genuine optimisation process excess fat can be pared off here and there. But if the machine is stuck with a particular minimum size of wing, and therefore overall size and wing loading, none of this can be done. Inevitably the modified V3 machine was unsatisfactory and the V4 equally so, even though the later version was fitted with a smaller tailplane to match the smaller wing.

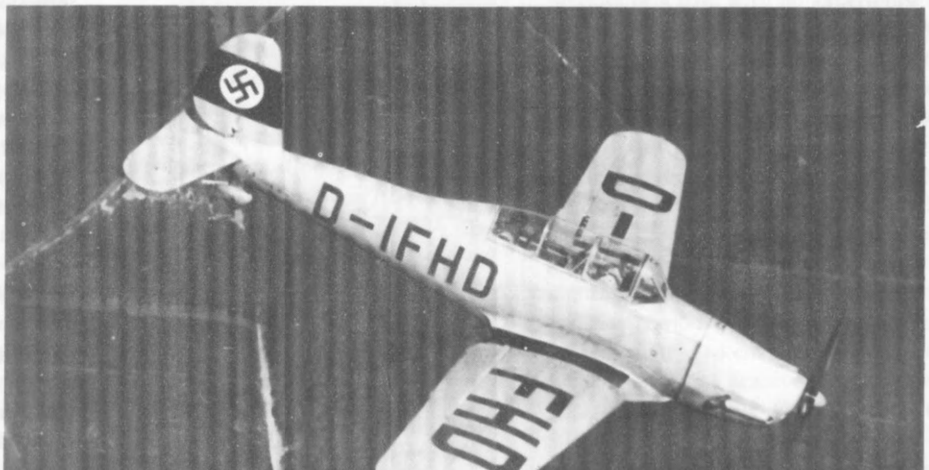
In spite of the decision in favour of the Bf 109, Heinkel continued to work on the development of the He 112, even though the company had a multitude of other projects in hand, covering an extremely wide variety of types. After seven prototype aircraft, V1 to V6 had been completed in vain, *i.e.* without getting any closer to an official contract, the V7, known as the He 112B, was ready. It was de facto a completely new aircraft. New wing, new fuselage, new tail surfaces — there was hardly anything left of the old He 112. In this form the overall performance of the machine was equal to that of the Bf 109, which in the meantime had become the Bf 109B after certain minor modifications had been made. It is not known whether the He 112's original superiority in handling had been retained (every pilot who flew the first 112 praises them to high heaven), but the Luftwaffe had no interest. Series production of the Bf 109 was already under way.

How the funds for such a large programme were to be obtained was not quite clear. Germany's priority at this time was to attempt to barter goods or bring foreign exchange into the country, to pay for raw

Heinkel He 112B.



Arado Ar 96 V1.

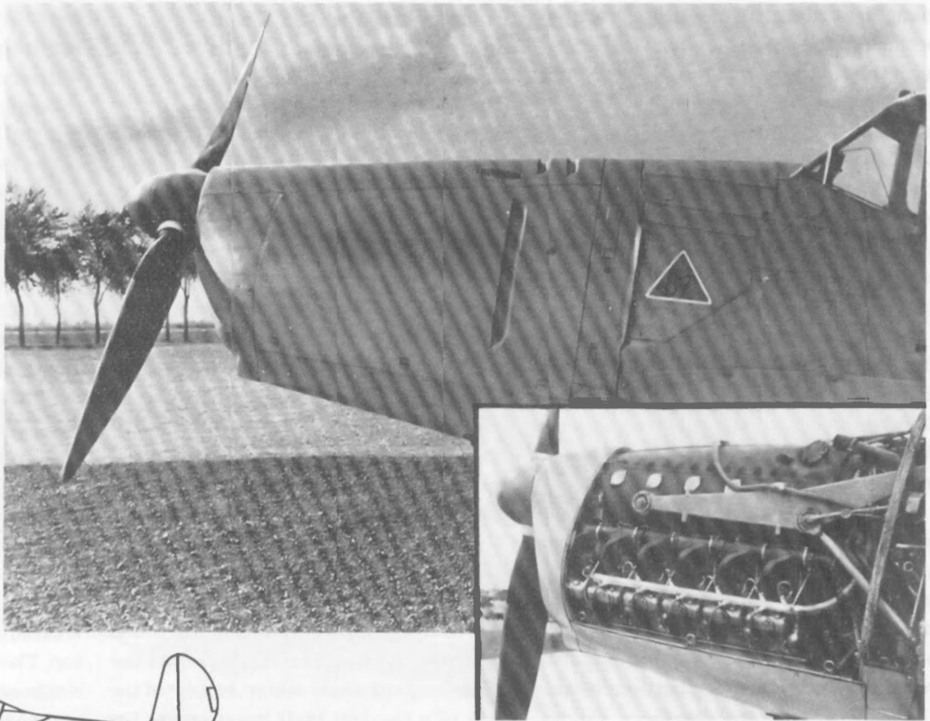


Arado Ar 96A trainer.

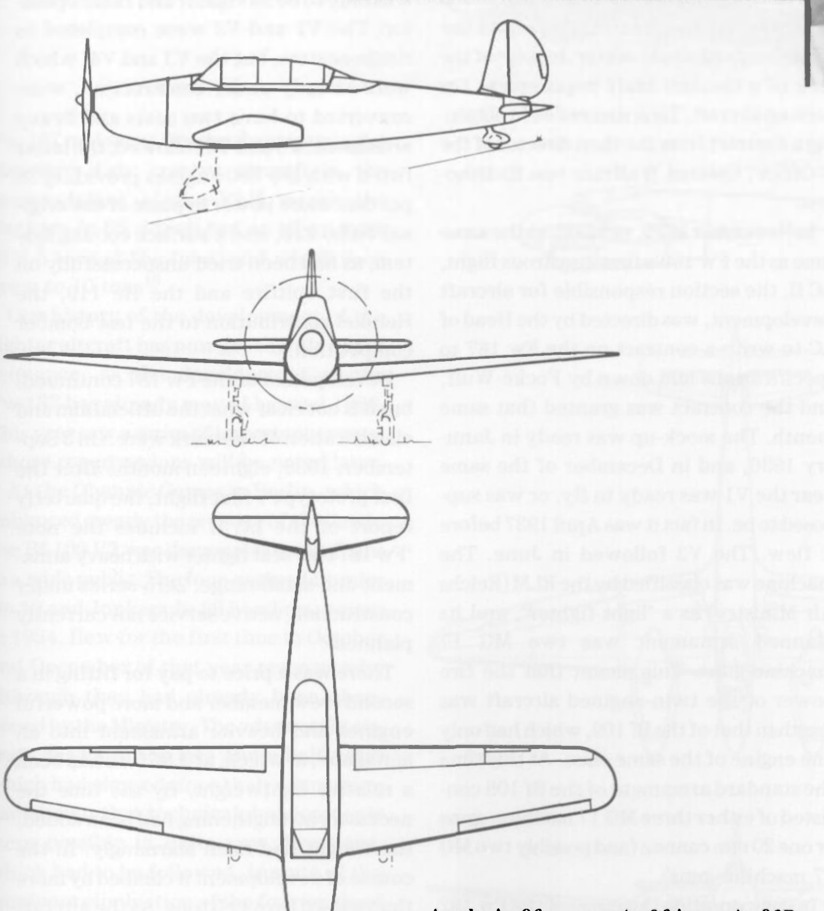
materials for armament and civil requirements on the international markets. In order to bring in foreign exchange, a large-scale aircraft export push was set in motion. A wide variety of aircraft was supplied to foreign countries. Heinkel received permission to offer the He 112 on the international market, where the company had maintained excellent connections for many years. A few machines went to Japan, some to Rumania, some to Spain. The Swiss would not do business, however; they wanted the Bf 109, and nothing else would do. The Air Ministry was forced to give its permission against its better judgement, as the Swiss made the supply of gear-cutting machines dependent upon the 109. So it was that the Bf 109 found its way to Switzerland.

The Government watched the expenditure rising, and became afraid. Although the sums seem small enough from today's point of view, the rate of armament had to be slowed. The budget of 3.7 billion Reichsmark, which had been earmarked for the General Staff for 1937, was cut back by one billion, or little more than a

Arado Ar 96B.



Argus As 410 engine installation.



Arado Ar 96	Ar 96A	Ar 96B
Wingspan	11.0 m	11.0 m
Length	8.0 m	8.8 m
Wing area	17.1 sq m	17.1 sq m
Empty weight	1,050 kg	1,300 kg
Equipped weight	1,130 kg	—
All-up weight	1,500 kg	1,750 kg
Argus engine	As 10C 240hp	As 410A 465 hp

quarter. The cutbacks were aimed in particular at technology, development and procurement. The build-up in personnel continued unabated. If the fighter pilots of the future were to be trained, a new aircraft was needed. It had to provide safe, low-cost training and, as far as possible, a risk-free transitional stage to the true fighter, without being as expensive to build, and above all without the fighter's thirst for fuel. It was to have space for a second pilot — the combat instructor — and be as similar as possible to the new fighter, the Bf 109, in terms of pilot's seat arrangement, pilot's view, flying qualities and operation — landing flaps, retractable undercarriage, radio system, etc.

The Arado Ar 96 Fighter Trainer

Arado's response was the Ar 96, which was to become the standard fighter-training aircraft until the end of the war. In the first version, of which only one example was built, both wings, the fuselage and the undercarriage were attached to each other by a central steel-tube bridge. The undercarriage legs were similar to those on the Ar 68, and retracted outwards into the wings. They were supported on two rubber-sprung struts and a bracing strut running aft, but they folded in a fore-and-aft direction instead of to one side. The result was a relatively narrow-track undercarriage. The whole arrange-

ment was then abandoned, probably because of the problems which had arisen with the first test versions of the Bf 109 and the Ar 96 VI. The steel-tube bridge structure was eliminated, and the wing became a one-piece two-spar structure. The single-leg undercarriage, fitted with rubber springing and oil-filled shock absorbers, was attached to the wing in a straightforward manner, and now retracted inwards.

The fuselage was built using the method first used on the Ar 80 *i.e.* right and left half-shells were constructed using longitudinal metal strips, and the two halves were riveted together after the fittings had been installed.

Plain landing flaps and ailerons were fitted. The ailerons were linked to the flaps, and moved down slightly when the landing flaps were lowered. Automatic slats of similar style to the Bf 109 were installed outboard on the wings. The tail surfaces [redacted]

Focke-Wulf Fw 187 Twin-engined Single-seat Fighter

The 1934 technical requirements for the armament aircraft IV which eventually produced the Bf 109, called for a single-engined single-seater. There was no mention of a twin-engined single-seater. The twin-engined armament aircraft III was to be a multi-seat destroyer. Focke-Wulf's Fw 57 was the company's contribution to that line of development, but it was soon abandoned as too large and heavy compared with the Bf 110.

After the inevitable failure of the single-engined Fw 159 single-seater in the pursuit-fighter competition, Kurt Tank, who had been technical director at Focke-Wulf since the end of 1932, pinned his hopes on the twin-engined machine again. He hoped to gain a contract to build a new two-seater capable of providing much higher speed and greater range than the [redacted]-seater. In spite of the [redacted] Staff requirement for [redacted] succeeded in obtain- [redacted] the then director of the [redacted] von Richtho-

[redacted], virtually at the same [redacted] first disastrous flight, [redacted] for aircraft [redacted] by the Head of [redacted] on the Fw 187 to [redacted] down by Focke-Wulf, [redacted] granted that same [redacted] up was ready in Janu- [redacted] of the same [redacted] to fly, or was sup- [redacted] was April 1937 before [redacted] in June. The [redacted] by the RLM (Reichs [redacted] 'light fighter', and its [redacted] was two MG 17 [redacted] meant that the fire [redacted]-engined aircraft was [redacted] Bf 109, which had only [redacted] class. At this time [redacted] ment of the Bf 109 con- [redacted] MG 17 machine-guns [redacted] (and possibly two MG [redacted].

[redacted] the range of the Fw 187 [redacted] greater, an advantage [redacted] a few years later. [redacted]), however, this did [redacted] attractive. The speci- [redacted] the single-seat fighter [redacted] half hours. Perhaps the [redacted] duration of the Fw 187 [redacted] emphasised more when the firm was pressing for its development, for the company data on expected speed did not seem credible. After all, the aerodynamics of the Bf 109B were not bad, and if it had been possible to unite the power of the Fw 187's two engines in one unit — twice 700 hp — it would have been as fast as the Fw 187 promised to be. In reality the Fw 187 turned out to be only 35 km/h faster than the Bf 109 (496 km/h compared with 460 km/h at 4,000 m altitude).

In spite of the advance in speed and range the Technical Office could not reconcile itself to the concept of the twin-engined single-seater or twin-engined 'light fighter'. Hardly had the leadership of the C-Office changed[15], than a new requirement was laid down: heavy armament consisting of two 20 mm cannon and two MG 17 machine-guns, and a second crew member, although the second man was only to be navigator and radio operator. The V1 and V2 were completed as single-seaters, but the V3 and V4, which were already under construction, were converted to have two seats and heavy armament. V5 and V6 followed, the latter fitted with DB 600 engines providing 35 per cent more power in place of the original Jumo 210, and a surface cooling system, as had been tried unsuccessfully on the first Spitfire and the He 119, the Heinkel contribution to the fast bomber competition.

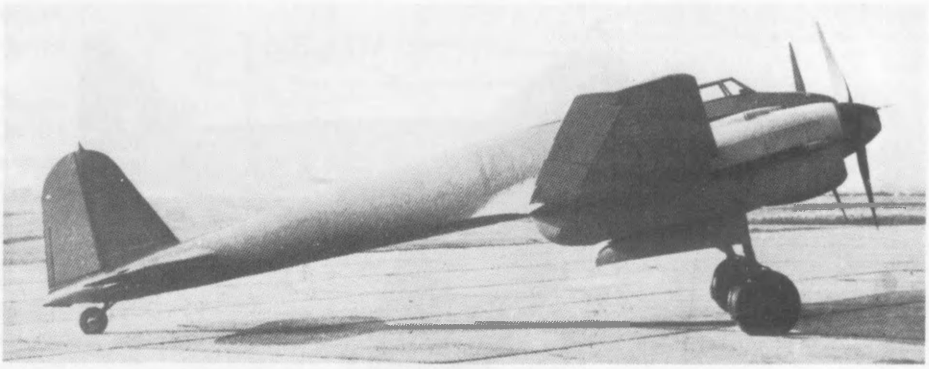
Development of the Fw 187 continued, but it is not clear what the official aim and classification of the work were. On 3 September, 1938, eighteen months after the first prototype's first flight, the quarterly report of the LC II includes the note 'Fw 187 two-seat fighter with heavy armament and small range. Zero-series under construction, active service not currently planned'.

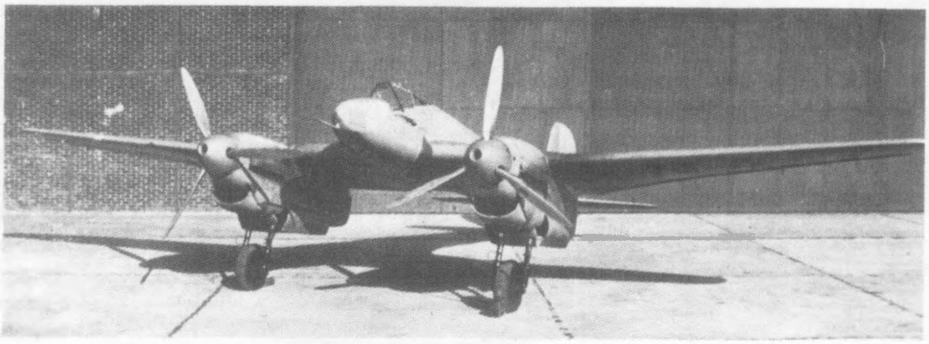
There was a price to pay for fitting in a second crew member and more powerful engines and heavier armament into an aeroplane, in which, at 3.85 tons had been a relative lightweight. By the time the necessary strengthening had been added, the weight had risen alarmingly. In the course of development it climbed by more than a third to over 5 tons. As the aircraft was classified in the quarterly report as a 'fighter with heavy armament and small range', it seems likely that little of its original range advantage remained.

The LC II quarterly report dated 3 September continues: 'Project preparation includes the light combat aircraft as heavy dive-bomber and heavy fighter'. The

Focke-Wulf FW 187

Wingspan	15.3 m
Length	11.1 m
Wing area	30.4 sq m
All-up weight	3,850 kg
Two Junkers-Jumo 210 D	680 hp
Maximum speed	457 km/h at ground level
Maximum speed	496 km/h at 4,000 m
Maximum speed	478 km/h at 6,000 m

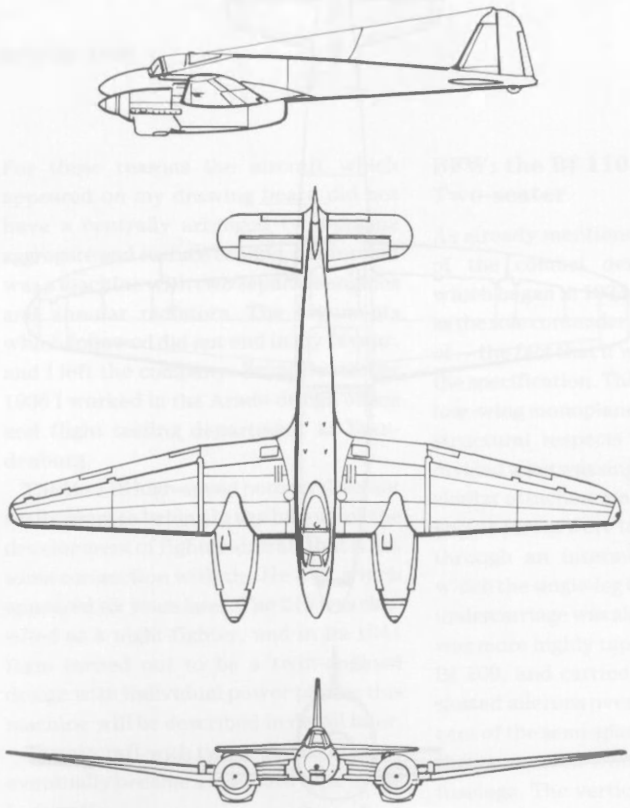




Fw 187 no longer fits the description, for the term light combat aircraft in the nomenclature of the RLM meant the Junkers Ju 88, which had an all-up mass of 8.5 tons at the time, and which soon grew to 10 tons[16].

Our history of the development of the fighter aircraft has now got slightly out of sequence, as the development of the Fw 187 has already moved beyond 1936. This year saw a series of important events, whose repercussions will be noted later.

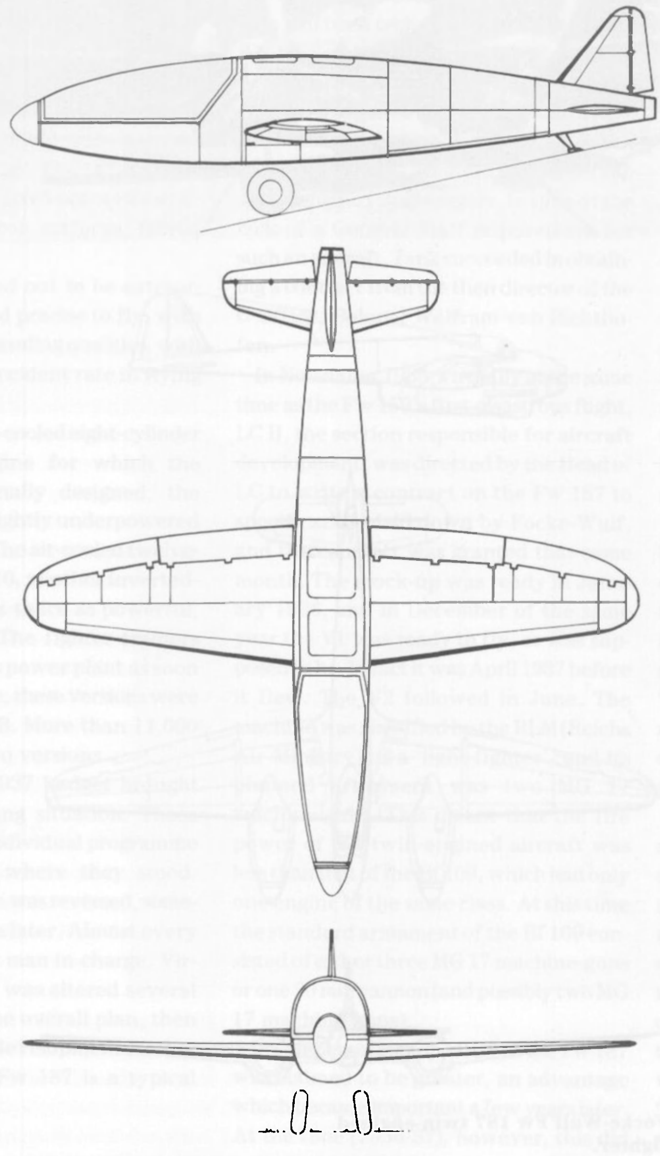
At the Olympic Games in Berlin, which enhanced greatly the prestige of the Reich, the Bf 109 V3 was demonstrated in flight to a wide public. The four-engined Dornier Do 19 and Junkers Ju 89 bombers, begun in 1934, flew for the first time in October and December of that year respectively, although they had already been abandoned by the Ministry. The advances in aircraft design in the two and a half years which had elapsed since their conception had shown that technical developments were possible in quite new directions, which had to be followed. In spite of the imminent elimination of the four-engined bomber from the programme, the Technical Office produced a specification for a new long-range bomber which had been initiated by studies made by the aircraft industry. Early in 1936 a four-engined aircraft was already taking shape on Heinkel's drawing boards. It subsequently received the designation He 177, and was



Focke-Wulf Fw 187 twin-engined fighter.

Heinkel He 176

Wingspan	5.00 m
Length	5.20 m
Wing area	5.4 sq m
Empty weight	780 kg
Equipped weight	900 kg
All-up weight	1,620 kg
Walter HWK-R1 203 rocket engine	600 kg thrust



Heinkel He 176. Experimental rocket-powered fighter.

destined to become one of the greatest disasters of the Luftwaffe. The four engines were arranged in pairs, each pair driving one propeller, and the overall impression was that of a twin-engined machine. At the same time work had already started on the design of a twin-engined high-speed bomber with the same engines. This bomber, developed independently by Heinkel, looked just like a large fighter aircraft, and was expected to equal or exceed the speed of the fighters. In the fighter sector Heinkel's Walter Günter was working on a further refinement of the 'cantilever low-winger with retractable undercarriage' concept, the later He 100, which set up a new world speed record in 1938.

During all this hectic work on piston-engined fighters, Heinkel believed that the time had come for a single-seater with rocket propulsion. The result was the He 176. The machine did demonstrate that it was possible to fly with a rocket engine, as aeromodellers had proved years before with their makeshift power plants, but in other respects it had no influence on fighter development. Nevertheless, at the time it was the only possible technique for reaching speeds substantially above those obtainable with piston engines and propellers.

Around this time Arado produced drawings for a destroyer, the Luftkreuzer (air cruiser), as it was termed in a long report written by Walter Blume. This work is mentioned again later in connection with destroyer development.

In April of this eventful year a young physicist, Hans von Ohain, who had just completed his doctorate, knocked at Heinkel's door with the idea of a gas turbine jet engine. As a direct result, the first jet aircraft in the world flew less that three years later. A whole book could and should be written about the history of the

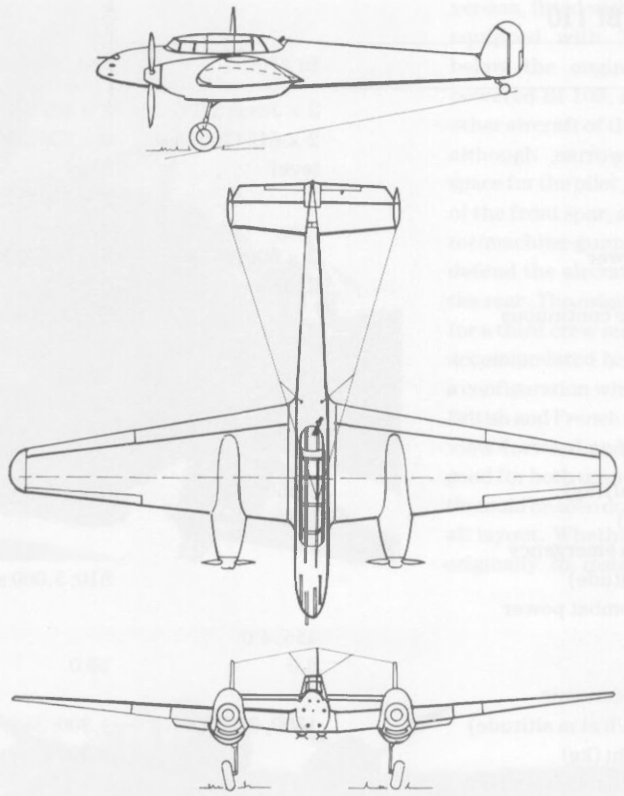
development of this concept, which turned the whole aviation world upside down.

At a more prosaic level: the Reichs Government sent fighter aircraft — He 51s — to support Franco in Spain. When these proved to be considerably slower than the Russian aircraft, the Bf 109 V3 was sent, and soon an entire Luftwaffe experimental command was set up there. The superior Russian machines were the Polikarpov 1-15 biplane with Gnome-Rhone high-altitude engine, and the even faster Polikarpov 1-16 — a low-winger which became well known in Germany under the name of Rata, with retractable undercarriage and the same engine as the 1-15.

In spite of the advances which were manifested in the new aircraft, the Arado Ar 68 — a braced biplane — was still being built in series, as the new aircraft were by no means ready for mass production. Heinkel also tried its luck once more with a revision of the He 51, aimed at increasing speed by a few more km/h. One of the factors which was expected to help was a smaller water/glycol radiator.

I[17] had been working in the the Heinkel design office and test-flying department since the beginning of the year, and flew in the new version with the task of measuring radiator performance. The flight was intended to consist of a climb at full throttle at the speed which gave maximum rate of climb, but I had to abandon the flight at an altitude of 2,000 m, as the temperature limit had been exceeded. At this point I decided to make wind tunnel experiments aimed at getting to the heart of the radiator problem. It had been my task to analyse radiator performance for some time, and it was my belief that the energy in the cooling water, which was equal to or greater than the energy available at the output shaft, should be put to better use than just drag production.

The high-performance aircraft projects under development in the Heinkel design office were planned for surface cooling, *i.e.* steam separated from the cooling water was to be condensed on the wing skin. At this time a trouble-free method of separating the steam had not even been produced on the test bench, and the problem of feeding and exhausting the condensate had not been tackled. The technical directors steadfastly pursued their concept while I attempted to gain extra trust by selecting optimum conditions for the cooling system installation.



BFW Bf 110B

For these reasons the aircraft which appeared on my drawing board did not have a centrally arranged twin-engine aggregate and surface cooling, but instead was a machine with two separate engines and annular radiators. The arguments which followed did not end in my favour, and I left the company. From December 1936 I worked in the Arado design office and flight testing department at Brandenburg.

The He 119 high-speed bomber does not really seem to belong in the history of the development of fighter aircraft, but it has some connection with the He 219, which appeared six years later. The 219 was classified as a night-fighter, and in its 1941 form turned out to be a twin-engined design with individual power plants; this machine will be described in detail later.

The aircraft with two separate engines eventually became a standard type in the Luftwaffe.

BFW: the Bf 110 Twin-engined Two-seater

As already mentioned in the description of the combat destroyer competition which began in 1934, the Bf 110 ended up as the sole contender, despite — or because of — the fact that it was far removed from the specification. This cantilever all-metal low-wing monoplane was similar in many structural respects to the Bf 109. The divided wing was single-sparred, with very similar attachments at the fuselage. The engine forces were transferred to the spar through an intermediate structure, to which the single-leg backwards-retracting undercarriage was also attached. The wing was more highly tapered than that of the Bf 109, and carried automatic slats and slotted ailerons over the outboard 40 per cent of the semi-span. The slotted landing flaps extended from the ailerons to the fuselage. The vertical stabiliser took the form of twin fins, intended to provide an unobstructed field for the gunner. The tailplane was adjustable in flight, also as on the Bf 109. Fuel was accommodated in the inboard wing section between fuselage and engine nacelles in two tanks on each side, fore and aft of the spar. The initial

Specification of Bf 110

Type	Bf 110B-1	Bf 110C/D/E	Bf 110F-2	Bf 110G-2
Engines	2 × Jumo 210G	2 × DB 601A	2 × DB 601F	2 × DB 605
Take-off power	2 × 515 (700) sea level	2 × 730 (990) sea level	2 × 990 (1350) sea level	2 × 1085 (1475) sea level
Emergency power		2 × 750 (1020) 4,500 m	2 × 970 (1320) 5,100 m	2 × 1000 (1365) 5,700 m
Climb and combat power	2 × 500 (675) 3,800 m	2 × 705 (960) 5,000 m	2 × 880 (1200) 5,100 m	2 × 920 (1250) 5,300 m
Maximum permissible continuous power		2 × 630 (860)	2 × 620 (840) 5,100 m	2 × 735 (1000) 5,500 m
Wingspan (m)	16.9	16.3	16.3	16.3
Length (m)	12.8	12.1	12.1	12.1
Wing area (sq m)	39.3	38.5	38.5	38.5
Airframe weight (kg)		5,200	5,600	5,700
All-up weight (normal) (kg)	5,650	6,750	7,100	7,300
Internal fuel load (kg)	940	940	940	940
Maximum speed with emergency power (km/h at m altitude)		510; 5,000 m	570; 5,000 m	595; 6,100 m
Maximum speed at combat power (km/h at m altitude)	455; 4.0		550; 5,700 m	575; 6,000 m
Service ceiling	8.0	10.0	10.9	11.0
Calculated range at economic cruise speed (km; km/h at m altitude)	1700; 320; 3.0	1,300; 380; 5,000 m	1,200; 400; 6,000 m	1,000; 450
Overload flying weight (kg)		8,900	9,300	9,300
Supplementary external fuel load (kg)		2 × 665	2 × 665	2 × 665
Calculated range with internal fuel (km) with maximum bomb load and economic cruise speed (kg: km/h) — Out and return flight		1,200; 375/390; 5 2,400; 336/390	1,200; 360/430 2,000	1,000; 450
Calculated range with maximum supplementary fuel load (km) with bomb load and economic cruise speed (kg: km/h) — Out and return flight		500	500	
Armament	4 fixed MG 17 machine-guns in fuselage, 1,000 rounds per gun	4 MG 17	4 MG 17	2 MG 17 2 MG 151
	3 fixed MG FF machine-guns in the fuselage, 180 rounds per gun	2 MG FF	2 MG FF	2 MG FF 1 MG 81
	1 movable MG 15 machine-gun, 750 rounds	1 MG 15	1 MG 15	additionally 2 × MG 151 machine guns below the fuselage if no bombs fitted

Notes:
110B-1; C/D/E measured values
F and G calculated values
As of 1.1.1942

Possible bomb loads for D and E
2 × 250, 2 × 500; 2 × 50/PC 1000 or combination 1 × 1000 + 1 × St 250 plus 4 × 50, 1 × SC 1000 + SD 500. C without releasable weapon

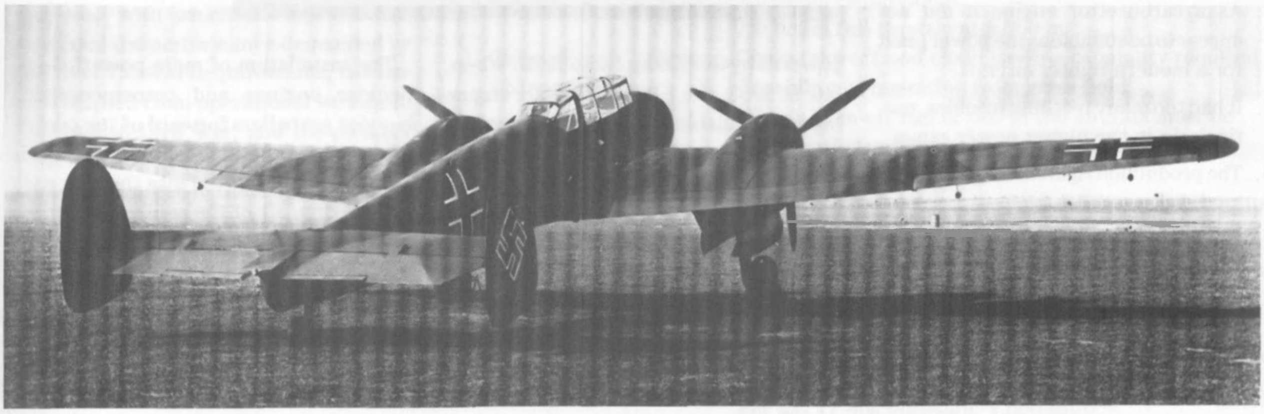
D with fuselage and supplementary tank
E additional wing bombs up to 4 × 50 kg
D-4, C-5 reconnaissance

F-3 reconnaissance
F-4 night-fighter
G-3 reconnaissance
G-4 night-fighter

The Bf 110 must undertake the roles of light bomber, reconnaissance and night-fighter in addition to its basic task as destroyer or heavy fighter.

Bf 110B.

version, fitted with Jumo 210 engines, was equipped with 'belly radiators' slung below the engines, as on the Jumo-powered Bf 109, and, incidentally, most other aircraft of the period. The fuselage, although narrow, provided adequate space for the pilot, seated directly in front of the front spar, and for the radio operator/machine-gunner, whose task was to defend the aircraft against attacks from the rear. The original specification called for a third crew member, and he could be accommodated between them. This was a configuration which was also adopted for British and French aircraft at the time. The view forward and above was extremely good for both crew members, whereas little could be seen downward with this overall layout. Whether it had been planned originally to install a heavier forward



Bf 110B.

Bf 110B.

armament than the four 7.9 mm MG 17 machine-guns, which were only fitted to the third test machine, has proved impossible to discover; the 1934 technical-tactical requirement called for two 20 mm cannon (and one twin machine-gun for defence).

In terms of speed the Jumo 210-powered Bf 110 exceeded handsomely the requirements of the armament aircraft III, for which it had been built in the first place, but its maximum altitude of 8,000 m was substantially lower than the requirement of 10,000 m. The only recourse here was more powerful engines. The V3 had been planned for the DB 600 engine, and this engine was also required for the Bf 109 in the interests of increased performance, but the unit turned out to have three faults which rendered it unsuitable for the production 109 and 110. The faults were:

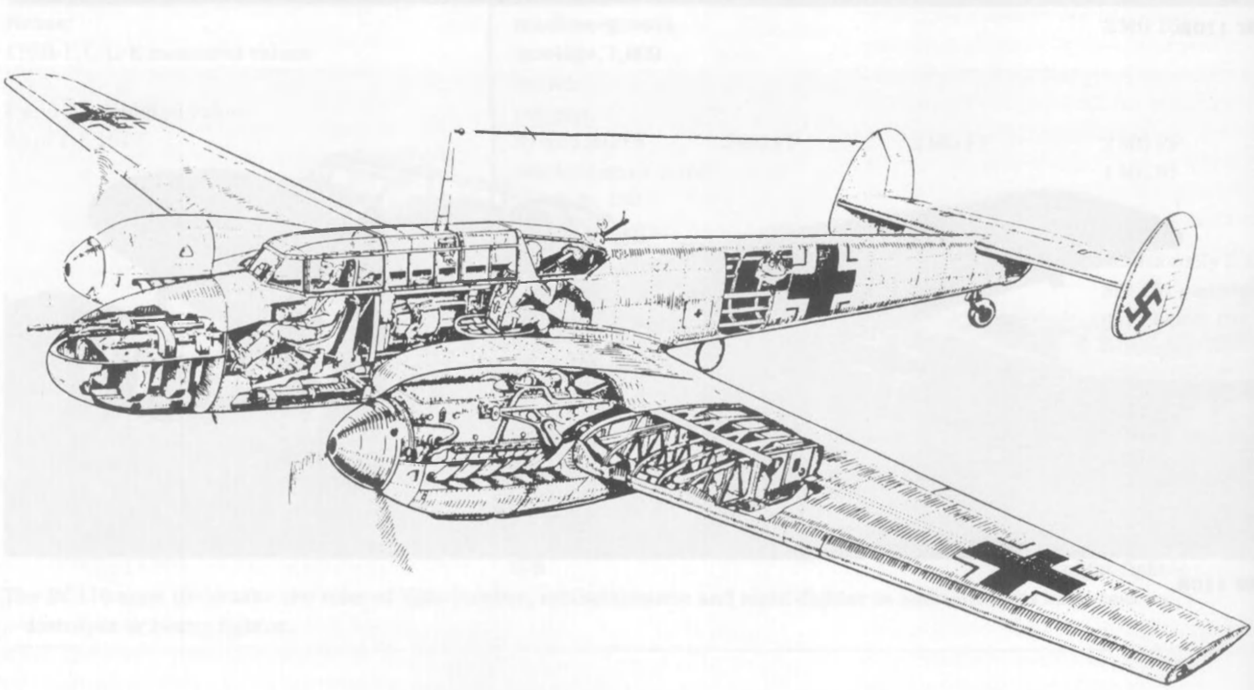
1. As a carburettor engine it did not appear to be suitable as the power plant for a modern fighter aircraft.
2. It had too many teething troubles, particularly in the higher power range.
3. The production figures for the immediate future were far too low to support a second programme (let alone a third) in addition to He 111 bomber production.

In consequence the Bf 110 had to go into series production in its Bf 110B-1 form, powered by the 700 hp Jumo 210D. When, late in 1938, the 1,000 hp DB 601 engine became available in sufficient numbers, it became the standard power plant for the Bf 110 in its C/D/E variants.

In the summer of 1939 the aircraft built with the Jumo 210 were withdrawn from combat formation and transferred for training purposes. The Chief of Training Authority noted on 7 July the 'introduction of the Bf 110B-1 aircraft type.'

Bf 110B.

The installation of more powerful *i.e.* heavier engines and correspondingly heavier propellers forward of the centre of gravity meant that the new larger radiators had to be shifted into the rear part of the wing, aft of the centre of gravity, just outboard of the engine nacelles. There may also have been aerodynamic reasons for this. The new layout necessitated a rather complex mechanism for operating the flaps which controlled the airflow



Bf 110B.

through the radiator in parallel with the wing flap setting. Otherwise the structure remained virtually unaltered, apart from necessary strengthening.

With the E version the Bf 110 had become a sort of Jack of all trades which could be equipped for an immensely wide variety of duties simply by adding appropriate equipment and fittings. It was often the case that the machine proved better at these tasks than at those for which it had originally been designed.

Even before the prototype aircraft for the C/D/E series had been completed, the Office established new technical requirements which the aircraft under development could not meet.

The Tactical and Technical Requirements for Fighter Aircraft at the end of 1936

The ease with which the fighters had exceeded the performance demanded by the 1934 Tactical Requirements, the lessons learned from operational service in the Spanish Civil War, and the possibly somewhat unscrupulous promises from industry, resulted in the Ministry making a re-appraisal of their tactical and technical requirements at the end of 1936. These new requirements were to make great demands on both the aircraft and the aero-engine industry. The crucial aspect was maximum speeds of 600 km/h at 6,000 m altitude for the single-seat fighter and 550 km/h for the heavy fighter, which was to be a twin-engined two-seater with wing-mounted engines. It was not sufficient for these speeds to be achieved with emergency boost power; it had to be possible to maintain the quoted speeds for several periods of up to 20 minutes, *i.e.* with what was termed increased continuous power. The fuel supply for the single-seater was to be sufficient for one and a half hours' duration at full throttle at 6,000 m altitude; for the two-seater the figure was 3 hours. The tables (somewhat abbreviated) show the levels of performance that it was thought could and must be expected from early experience with the Bf 109 and Bf 110.

To achieve a speed of 600 km/h at 6,000 m altitude with an aircraft the size of the Bf 109B, demanded an engine which could produce 1,100 hp at that altitude. The existing 109 had a top speed of 420 km/h at sea level (with antenna and weapons), with its 700 hp engine. This was a simple schoolboy calculation, but begs the question of how to install an engine producing 60 to 70 per cent more power without fitting larger oil and water radiators, a larger intake, without adding weight and without providing more space for power plant and fuel. In any case an engine which could produce 1,100 hp at an altitude of 6,000 m was far from being available when the requirements were laid down, far less a unit capable of that power for continuous periods. In fact it was only four years later that such an engine was produced, in the high-pressure atmosphere of wartime. It was clear then, that if the requirements really were to be met, industry had

Tactical-technical requirements for the light fighter aircraft (1936-37)

1. Tactical application:	a) Attack individually and in formation against combat aircraft, reconnaissance and fighter aircraft from all directions. Operations day and night. b) Secondary task: low-level attack against live targets.
2. Aircraft type and its special characteristics:	Single-engined, single-seat. Assessment: speed rate of climb manoeuvrability Instruments for brief periods of blind flying (20 minutes duration)
3. Speed:	V_{max} at 6,000 m = 600 km/h V_R at 6,000 m = 400 km/h (cruise speed) at constant cruise speed.
4. Climb rate:	6,000 m in 6 minutes Working altitude 6-7,000 m Best performance at 6,000 m
5. Service ceiling:	12,000 m without bomb load
6. Duration:	Minimum requirement: 1½ hours full-throttle at 6,000 m
7. Take-off and landing characteristics	Chain take-off and chain landing capability required Capability of operating from grass field After a take-off run of 500 m the aircraft must be capable of clearing an obstacle 10 m high
8. Fixed armaments:	4 weapons: of which 2 heavy machine-guns (with explosive round of maximum efficiency) in the wings, uncontrolled firing. 2 MG 17 machine-guns on the engines, controlled firing. Ammunition: Per heavy machine-gun: 300 rounds Per MG 17 machine-gun: 1,000 rounds
9. Bomb equipment:	5 × 10 kg or 20 × 2.6 kg No aiming equipment. Combustible fuse against aerial targets.
10. Communications equipment:	Radio equipment with following range: at least 50 km at 6,000 m altitude for air-air; 200 km for ground-air, reception only; for transmission only: 'understood' signal (short R/T signal) If possible, target flight receiver.
11. Rescue and safety apparatus:	High-altitude oxygen apparatus for 1 hour at 6,000 m altitude Protection against ice formation on sight For cabin aircraft: Protection against ice formation on cabin windows Sliding side window, to permit formation flying in spite of icing
12. Defensive measures:	Camouflage paint scheme to guard against discovery from the air and the ground

to come up with some significant aerodynamic refinements.

The task set for the heavy fighter was far more difficult, because of the great range demanded (twice the flight duration), since the two aircraft were restricted to the same engines. The heavy fighter really needed much larger engines, but there were no larger engines in any development programme. At the time when the requirements were drawn up in 1936 hopes were still being pinned to refinements in aircraft design, aerodynamic refinements in particular, and to power increases from the 30-litre engines.

Entr'acte — Record Aircraft

Heinkel and Messerschmitt each wanted to get a head-start on the other by setting a new World Speed Record. Heinkel's effort was based on the He 100 and Messerschmitt's on the Me 209, a type number which covered a whole series of aircraft which had hardly anything in common apart from the number 209.

The Heinkel record aircraft was a development of the firm's new fighter which had been developed as a private venture. The company hoped that the superior performance of the new machine would help it win government fighter contracts again, after it had been pushed out by Messerschmitt's 109. The airframe of the He 100 had been shaped with the utmost care, with no projecting parts at all. Engine cooling was via the condensation of steam separated from the cooling water in the wings. The structure represented a

Tactical-technical requirements for the heavy fighter aircraft (1936-37)

1. Tactical application:	a) Attack individually and in formations up to Staffel (squadron) against combat aircraft, escort aircraft and long-distance reconnaissance aircraft over long distances. Making attacks from behind, behind and above, behind and below in direction of flight, or at acute angle to direction of flight Day operation; take-off and landing very often at night b) Supplementary task: low-level attack against enemy ground defences
2. Aircraft type and its special characteristics	Twin engines, wing-mounted, multi-seat Assessment: speed range rate of climb Full instrumentation for blind and long-distance flying Full night-flying equipment (searchlights) Radio operator located immediately behind the pilot
3. Speed:	V_{max} at 6,000 m = 550-600 km/h V_R at 6,000 m = at least 400 km/h at constant cruise engine speed
4. Rate of climb:	5,000 m in 8 minutes Working altitude 6-7,000 m
5. Service ceiling:	10,000 m without bomb load
6. Duration:	3 hours full throttle at 6,000 m
7. Take-off and landing	Chain take-off and landing capability. Use of grass airfield or operational airfield After a take-off run of 600 m the aircraft must be capable of clearing an obstacle 20 m high
8. Fixed armament:	1. Attack 2 heavy fast-firing rate weapons Calibre at least 20 mm; maximum possible firing range; explosive round Installation of semi-fixed, uncontrolled firing, 2 × 4

	MG 17 machine-guns, fixed installation, uncontrolled firing
	Operation by pilot
	Ammunition:
	Per heavy fast-firing rate weapon = 300 rounds (for 20 mm calibre)
	Per MG 17 machine-guns = 1,000 rounds
	Sight: For firing at ranges:
	600-50 m for heavy weapons and 400-50 m for light weapons
	2. Defence
	One double MG 15 machine-gun angled up and back
	Ammunition: approx. 1,000 rounds
	Firing field: vertically from 0°-30° up, horizontally 30° to both sides
	Sight for high speeds
9. Bomb equipment:	10 × 10 kg or 40 × 25 kg
	Simple aiming device for aerial targets
10. Communications:	R/T apparatus for transmitting and receiving on all frequencies allotted to Luftwaffe
	Retractable D/F loop
	Target-flying equipment
	For the pilot R/T with 50 km range for air-air, 200 km for ground-air, reception only
	Firing device for 5 signal cartridges
11. Rescue and safety equipment	High-altitude oxygen equipment for 2 hours at 6,000 ,
	Protection against ice formation on sight and cabin windows
	Protection against ice formation on airframe
	Sliding side window, to permit formation flying in spite of icing
12. Defensive measures:	Camouflage paint scheme against discovery from the air and the ground

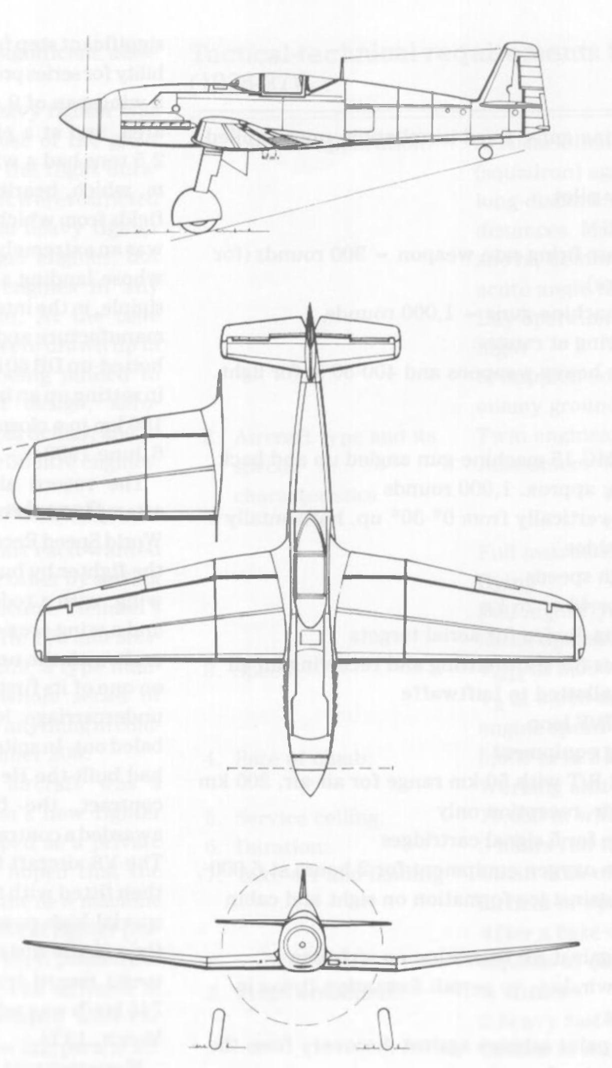
significant step forward in terms of suitability for series production. The fighter had a wingspan of 9.4 m and 14.4 sq m wing area, and at a planned all-up weight of 2.5 tons had a wing loading of 175 kg/sq m, which, bearing in mind the grass airfields from which it was likely to operate, was an extremely high figure for a fighter whose landing aids had been kept very simple, in the interests of straightforward manufacture and low drag. Fitted with a hotted-up DB 601 the machine succeeded in setting up an international record over 100 km in a closed circuit of 635 km/h on 6 June 1938.

The record aircraft, with which an attempt was to be made on the Absolute World Speed Record, was developed from the fighter by building a completely new wing, with a reduced wingspan of 7.0 m and a wing area of 11 sq m. The first aircraft with the new wing, the V3 crashed on one of its first flights when one of the undercarriage legs jammed. The pilot baled out. In spite of the fact that Heinkel had built the He 100 without an official contract, the firm was subsequently awarded a contract to build ten machines. The V8 aircraft from the test series was then fitted with the new wing and a very special high-power engine. For the first time in the history of flight an absolute speed record (close to ground level) of 746 km/h was achieved by Germany on 3 March, 1939.

Messerschmitt too had developed a special-purpose aircraft, the Me 209, with exactly the same goal. Without consider-

Heinkel He 100 V8, which brought the absolute World Speed Record home to Germany for the first time at 746 km/h.

Opposite: Heinkel He 100 fighter with evaporative cooling, on which the record-breaking aircraft was based.



Heinkel He 100	He 100	He 100 Rekord
Wingspan	9.4 m	7.5 M
Length	8.2 m	8.2 m
Wing area	14.6 sq m	11.0 sq m
Empty weight	1,810 kg	
Equipped weight	2,010 kg	
All-up weight	2,500 kg	
Daimler-Benz DB 601M	1,100 hp	
DB601R		2,000 hp

ing any possible subsequent use for the machine as a fighter, the company designed an aircraft of similar size to the He 100. This was inevitable, as one DB 601 and one man cannot be accommodated in a machine below a certain size. Wingspan, wing area and fuselage length were similar to those of the He 100-Rekord. The Heinkel had the advantage that its sire was a slightly larger aircraft, and possessed large tail surfaces and thus good handling right from the start. The Me 209, on the other hand, had the minimum possible wetted area, and the tail surfaces in particular were probably excessively small. By the standards of 1938, the aircraft had miserable flying characteristics, but a good, experienced pilot could still manage it, and the machine was not intended to be a practical all-round aircraft. The radiator problem had been solved simply: the quantity of water required to maintain a balanced temperature was evaporated from the cooling water as it left the engine, and blown out into the air. This quantity was then made up from a fresh water tank. At full power the engine consumed about 30 litres of water per minute, which was replenished from the 450-litre water tank.

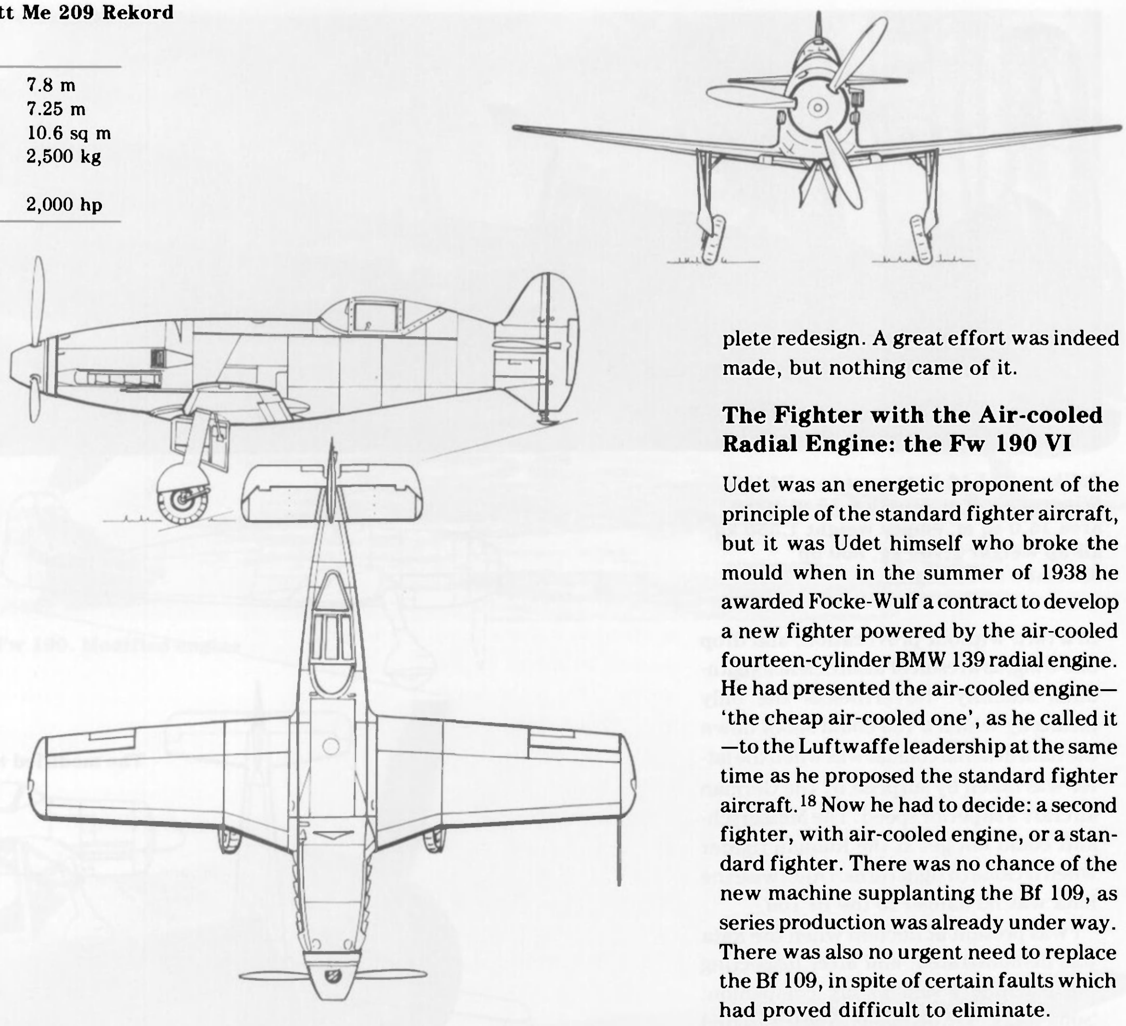
As in Heinkel's record effort, one aircraft was lost during flight testing, in this case the machine intended for the actual record flight — the V2. On 26 April the V1 achieved a speed of 755 km/h over the 3 km course. Thus it happened that the world record set by the He 100R just eight weeks previously was bettered by 8½ km/h, slightly more than the one per cent margin required for recognition as a new world record.

Neither record attempt had any effect on fighter aircraft development. Heinkel's record aircraft was derived from a fighter which the Office did not want, because of the machine's surface cooling system, and the official wish to stick with a standard fighter. In theory a fighter could have been derived from the Messerschmitt aircraft, but it proved impossible without a com-

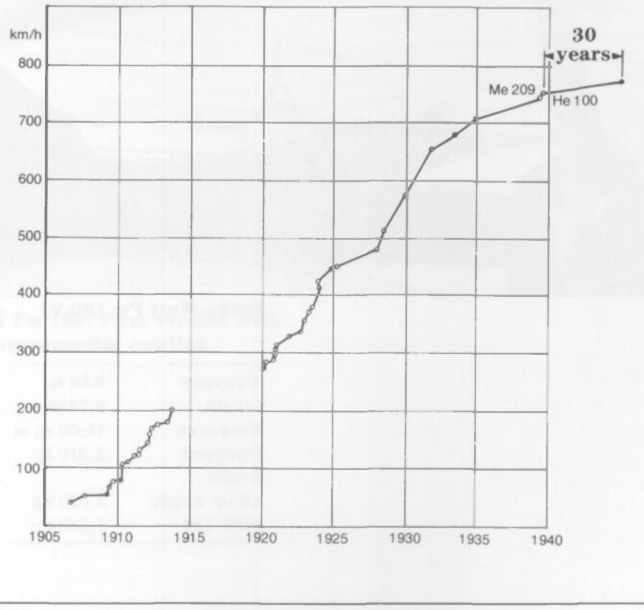
Messerschmitt Me 209R, which wrested the speed record from Heinkel eight weeks later, with 755 km/h.

Messerschmitt Me 209 Rekord

Wingspan	7.8 m
Length	7.25 m
Wing area	10.6 sq m
All-up weight	2,500 kg
Daimler-Benz DB 601 AR	2,000 hp



The development of the World Speed Record for piston-engined aircraft.



plete redesign. A great effort was indeed made, but nothing came of it.

The Fighter with the Air-cooled Radial Engine: the Fw 190 VI

Udet was an energetic proponent of the principle of the standard fighter aircraft, but it was Udet himself who broke the mould when in the summer of 1938 he awarded Focke-Wulf a contract to develop a new fighter powered by the air-cooled fourteen-cylinder BMW 139 radial engine. He had presented the air-cooled engine—'the cheap air-cooled one', as he called it—to the Luftwaffe leadership at the same time as he proposed the standard fighter aircraft.[18] Now he had to decide: a second fighter, with air-cooled engine, or a standard fighter. There was no chance of the new machine supplanting the Bf 109, as series production was already under way. There was also no urgent need to replace the Bf 109, in spite of certain faults which had proved difficult to eliminate.

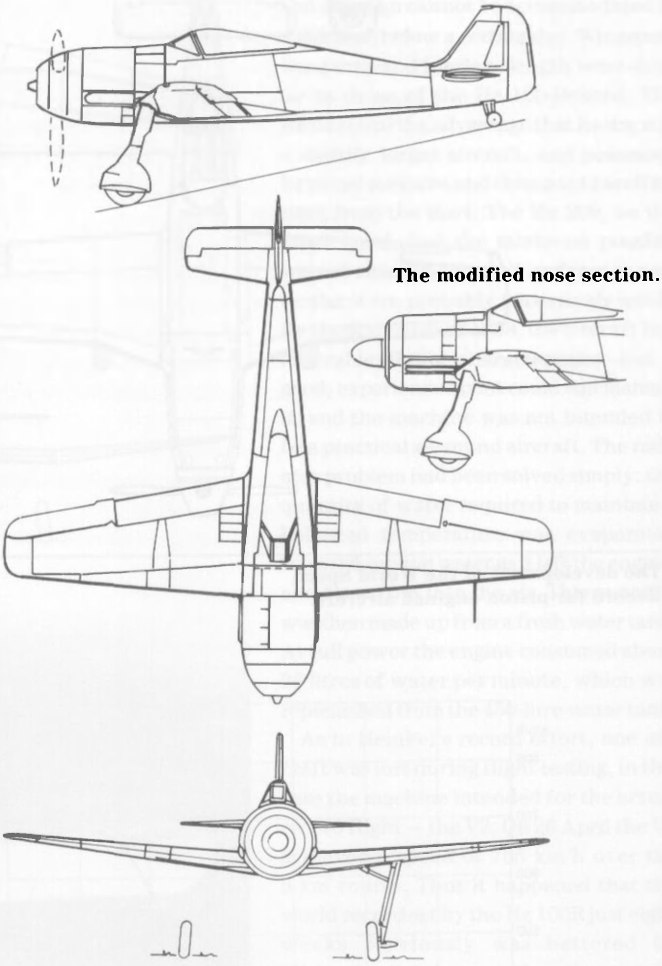
How this particular ball was started rolling is not quite clear now. It is highly likely that the Russian Polikarpov I-16 played some part. This was a single-seat fighter used in the Spanish Civil War; a cantilever low-wing monoplane with retractable undercarriage and air-cooled radial engine. In 1938 a captured machine had been brought to Germany, and was exhaustively test-flown at Rechlin, compared with the Bf 109 in mock combat and was also made accessible to the industry. In fact the aircraft possessed certain characteristics which were very attractive to ordinary pilots. It had an air-cooled engine and was very primitive in construction and fittings. It had no hydraulics and no electrics, the undercarriage was raised by a hand-actuated crank, landing flaps and radiator flaps were set by hand, etc. The Bf 109 was superior to the I-16 Rata in speed, but inferior in terms of manoeuvrability, because of the Russian machine's lower wing loading and smaller size. By German standards the handling was very poor; the machine tended to stall

Polikarpov I-16 Rata next to a Bf 109. Wingspan 9.0 m, length 6.15 m, wing area 15.0 sq m, empty weight 1,350 kg, all-up weight 1,700 kg, 800 hp Shvetsov M-60 engine.

in a turn without provocation, and drop one wing, as a result of insufficient longitudinal stability. Nevertheless the only means by which a 109 could shoot down the Rata in aerial combat was when the latter was taken by surprise by the German aircraft's superior speed. The Messerschmitt could not get at the Russian fighter when it came to tight turns. Otherwise the Rata was no danger to the Bf 109.

I was present at Rechlin when the Rata was demonstrated, and after inspecting the machine I said to my companion: 'something like this needs to be translated into German', *i.e.* built to German technical standards. We then proceeded to draw up a German version — a fighter with the air-cooled fourteen-cylinder BMW radial engine. The aircraft did look something like the later Focke-Wulfe Fw 190; how could it not have done? The single-seat fighter formula — single-engined cantilever low-wing monoplane with retractable undercarriage — was firmly established at home and abroad.

When we drew our sketches, our top priorities had been simplicity and safe flying characteristics, rather than any idea of exceeding the performance of the fighters with water-cooled engines. We knew that Udet had established a speed record of 635 km/h flying the Heinkel He 100, but in his official role he was not interested in the machine, in spite of its high speed. Walter Blume, Arado's technical director, showed little enthusiasm for our drawings, as he did not believe that the Office could be convinced of the idea. The LC II Office (aircraft development, including the fighter office) showed even less



The modified nose section.

Focke-Wulf Fw 190 V1

Wingspan	9.56 m
Length	8.73 m
Wing area	15.00 sq m
Equipped weight	2,310 kg
All-up weight	3,020 kg
BMW 139	1,500 hp

Focke-Wulf Fw 190. Modified engine cowling.

Focke-Wulf Fw 190. First version with through-flow propeller cowling.

enthusiasm. The first question concerned maximum speed. When we stated 600-650 km/h as a target figure, the officer shook his head: 'Messerschmitt has already submitted plans for a 720 km/h machine'. And we were waved away. There was no mention that any other company had obtained a contract to build a fighter powered by the fourteen-cylinder BMW engine. Later, when we received the Focke-Wulf 190 drawings for the version to be built in the Arado factory at Warnemünde, and compared the design with our plans, we assumed that either Tank, Focke-Wulf's technical director, had gone straight to the top, *i.e.* direct to head of the C-Office, as he had successfully done with the Fw 159 and Fw 187, or that Udet, without consulting his advisors and experts, had approached Tank himself; but that is speculation.

The Focke-Wulf 190 VI. The first version of the aircraft, the Fw 190 VI, was eventually developed into a very good fighter aircraft, which helped to bear a great part of the war effort. There were some problems on the way, but this is inevitable in aircraft development. It is likely that the top priority in the initial design had been the achievement of maximum possible speed. The machine's dimensions were kept as small as possible commensurate with the large and heavy 1,500 hp engine, with its diameter of 1.30 m. Wingspan and wing area were smaller than those of the Bf 109, against which Focke-Wulf felt it had to compete, and the overall length was only a few centimetres greater. An unusually large through-flow spinner, faired directly into the engine cowling, allowed the designers to keep the nose of the aircraft extraordinarily slender.

The intention was that this measure would reduce drag at the front end of the fuselage. Had there been practical high-speed wind tunnels in Germany, and had there been sufficient time to make wind-tunnel tests, then the firm would certainly have saved itself the effort; for a wasted effort it was. Very soon the new form of rotating cowl was replaced by a conventional cowling. One important innovation in this area was the oil cooler location behind the front of the engine cowling, which took the form of an armoured ring, protecting the oil cooler and cylinder heads from damage when fired at from the front. This clever arrangement contributed greatly to the aircraft's survivability during attacks on bombers and ground targets.

It took about a year for the aircraft to be ready for its first flight on 1 June, 1939. Tests showed that the flying characteristics — stability, control surface response and control forces, even at high speed — were satisfactory. The aircraft showed no pronounced tendency to drop a wing when stalled, and the wide-track, inward-retracting undercarriage made for safer landings. So far, so good. However, the aircraft had two characteristics which put a damper on the general enthusiasm. The engine proved to be anything but reliable, and power plant problems were a regular occurrence. The second drawback was that the cockpit became unpleasantly hot. One test pilot's initial assessment was that 'the Fw 190 is a pilot's frying pan'. In fact the high temperature of the cockpit was no surprise. It was a thin aluminium shell, washed all round by the hot air-cooled engine. Two broad bands of the cockpit were also subject to the much hotter exhaust gasses. A problem of this sort can be solved, but not overnight. Two years later, in a report dated 10 December, 1941, the Fw 190A and Bf 109F were compared. A serious complaint with the Fw 190 was excessive temperatures in the cabin.

After the haste with which the first prototype was designed and built, further development continued at a comparatively slow rate. But this was no fault of the firm.

The Political Events of 1938 and Their Consequences

Fighter aircraft

	Type	Number	Available	To be procured
3 fighter squadrons	Ar 65	36	–	36
3 fighter squadrons	CR 30*	36	–	36
3 fighter squadrons	He 38See	12	12	–
single-seat fighters	Ar 64	19	19	–
single-seat fighters	Ar 65	21	10	11
two-seat fighters	Al 84**	12	–	12

*The CR 30 was an Italian design by Fiat, the purchase of which was not completed, due to 'supply difficulties'.
**The Al 84 was the last Albatros two-seat fighter, which is said to have been built under collaboration between Albatros and Focke-Wulf in Bremen. Only three machines were completed.

The Preliminary Stages

The Bf 109E had only just been delivered to the Luftwaffe in quantity, and series production of the Bf 110C had only just begun, when, in the late summer of 1938, events on the political front brought everything into chaos. Suddenly it became necessary to rethink every element of re-armament planning, but the constant stream of new crises meant that nothing could be done. The Luftwaffe leadership was constantly torn this way and that between the demand for new, better hardware and the necessity of sticking with what they had because of the production situation; over and above this came the pressing need to restrict armament spending.

These developments are difficult to understand without some knowledge of Germany's political situation regarding defence. After the First World War Germany found itself virtually surrounded either by former enemy powers or by newly founded states which had been sliced out of the territory of the Reich or Austria-Hungary. All these neighbours had substantial land-based and aerial armed forces, whereas the paltry Reichswehr (Reichs Army) numbered just one hundred thousand men, and had no air force at all. There seemed to be no possibility of defending the country against neighbouring nations' demands for more territory, which were constantly being urged by certain political circles abroad. This applied in particular to East Prussia, which amounted to roughly eight per cent of the Reich's territory, but which was completely separated. The Reichswehr leadership lived under the constant nightmare of a combined action by France, Poland, Czechoslovakia and perhaps also Lithuania. For many years this was how Germany viewed the 'enemy', and military planning was done with this threat constantly in mind, even though the plans were not always completely logical. Naturally the Reichswehr leadership was equally painfully aware of the inadequacy of an air force which numbered just four fighter squadrons of twelve aircraft each, and many expansion plans were drawn up. One study, dated 1 February, 1932, prepared by the In 1 foresaw an 'A-Luftwaffe 1938' totalling 1,056 aircraft. On 28 July of the same year a decree setting up the aerial forces of the 'Peace-time Army' was passed, and on 10 August, 1932, the 'organisational basis for setting up aerial combat forces' was worked out. On 11 November, 1932, the In 1 produced a report on the 'inadequate state of Luftwaffe crew and armament'.

The scope of these plans remained very modest, for the means available were strictly limited (see table, left).

Plans for further expanding the Luftwaffe were then completed, but there seemed to be no great urgency, especially when one considers the strength of the foreign countries' aerial forces.

1. On 19 June, 1933, a discussion was held between Colonel von Reichenau and Secretary of State Milch. It was decided that an aerial force of around 600 aircraft would be created by the end of the first two armament periods (summer/autumn 1935). The force was to include two fighter wings, each of 36 aircraft. It was also agreed that no naval fighter formations should be set up, with the exception of the He 38 squadrons already in existence.

2. On 12 July, 1933, just four weeks later, the programme just agreed was cut back by half, from 51 squadrons to 26 'due to lack of personnel and aircraft'. The two fighter wings (six squadrons) were retained.

3. On 28 August, 1933, seven weeks later, the number of fighter squadrons to be set up in the second armament period (1935) was reduced by half (3), by order of the Reichs Air Minister. At the same time the five bomber and five auxiliary squadrons were formed into 16 bomber and one auxiliary bomber squadron.

4. On 25 May, 1934, nine months later, the Reichs Air Minister determined the composition of the third procurement period (1 October, 1936) as below:

Combat formations:		
Position	1 October, 1935	7 wings (Geschwader)
To be added	1 October, 1935	8 wings
Position	1 October, 1936	15 combat aircraft wings
Fighter formations:		
Position	1 October, 1935	(2) wings = 3 squadrons (Staffeln)
To be added	1 October, 1936	6 wings = 18 squadrons
Position	1 October, 1936	8 wings = 21 fighter squadrons
Naval:		
Position	1 October, 1935	1 fighter squadron (Jagdstaffel)
To be added	1 October, 1936	1 fighter squadron
Position	1 October, 1936	2 fighter squadrons

5. On 3 December, 1934, the Chief of Naval Forces called for three 'fighter dive-bomber squadrons' for service on aircraft carriers.

6. On 29 August, 1935, the armament plans which then existed foresaw the following situation on 1 October, 1938: Land: 204 squadrons in total, including
90 combat squadrons
45 fighter squadrons
6 auxiliary combat squadrons
Sea: 3 coastal fighter squadrons
3 carrier fighter squadrons

7. On 15 April, 1936, by 'command of the Reichs Air Minister, the plans for setting up fighter formations are hereby amended ... The shortage of personnel, in particular officers, forces us to modify the plans for establishing fighter formations. By 1 April, 1938, 48 squadrons will be founded instead of 60 squadrons.' (Researched and compiled by the author.)

The necessity to save money was also very evident in the field of development, especially when it is realized that hardly anything which was then in use was fit to be kept. An excerpt from the budget plan of 1933, drawn up on 21 July, 1933, by Wimmer, the chief officer in the Air Ministry, makes it clear that less than 20 million Reichsmark were available for technical development, and around half of it was to come from the labour procurement programme.

After initial growth the development budget became tighter. For 1937 a 40 per cent reduction in development personnel was planned. Nevertheless, the Luftwaffe gradually grew, and changed from a force whose task was to defend the country against the perceived French-Polish-Czechoslovak threat, into one which could present its own threat. In 1938 the Reichs Government, *i.e.* Adolph Hitler, began to exploit the German superiority in arms in order to achieve his political aims abroad. In the spring Austria was annexed; very soon after this, actions were undertaken which led to the secession of the Sudetenland from Czechoslovakia.

The growing might of the Reich now inevitably brought Britain into the game, as it was bound to become one of Germany's enemies. The General Staff suddenly realised in alarm that no provision at all had been made for this eventuality. The bombers' range was insufficient and that of the fighters was definitely too short. Nevertheless, the Czech crisis made a confrontation with Britain inevitable.[19]

Budget plan 1933, technical development

	Overall cost Millions RM	From labour procurement program Millions RM	%
Aircraft and propellers	8,670,254.00	4,662,000.00	54
Engines	6,702,200.00	2,478,000.00	37
Other equipment	3,622,000.00		
Total technical development	18,994,454.00		

Test centres: Staaken, Rechlin, Travemünde

Overall budget	3,162,500	inclusive of flight pay and travel costs
Personnel expenses	743,000	
Labour costs	430,000	

'Peace was saved' by the Munich Agreement of 29 September, 1938, but the General Staffs and everyone with any understanding on both sides knew that an armed conflict had only been postponed. The rate of armament had to be increased greatly. The 1930-40 aircraft programme drawn up by the Luftwaffe General Staff and the rough budget estimate for technical development are proof of this.

This document appears to be unbalanced, in that no mention is made of the He 111 medium bomber. Could it have escaped the General Staff that the He 111 production represented a large percentage of aerial armament at the end of 1938?

Procurement programme of 7.1.1938, target 1.4.42

'Re. concentrated aircraft programme.

In his speech on 26.10.1938 the Herr General Field Marshal Goring declared that the numbers of aircraft formations and aircraft types were to be as follows:

58	combat Wings, aircraft type: Ju 88; He 177 as many He 177 as possible, at least 4 Wings
16	destroyer Wings, aircraft type: Me 210; Bf 110 as many Me 210 as possible, at least 7-8 Wings
8	stuka (dive-bomber) Wings, aircraft type: Me 210, initially Ju 87B
16	fighter Wings, aircraft type: Bf 109 and further developments
10	groups short-range reconnaissance aircraft aircraft type: Hs 126; Fw 189
10	squadrons long-range reconnaissance aircraft (Army) aircraft type: Do 17P, Z; Fw 189 (?)
13	squadrons Ob.d.L., (Commander-in-Chief of the Luftwaffe), aircraft type: Ju 88; He 177
1	battle Wing, aircraft type: Fw 189
4	transport Wings, aircraft type: Ju 90. If procurement of the full number of Ju 90 proves impossible, the original equipment is to be procured again.
500	ships' and carrier aircraft, formations to be decided with Ob.d.M. (Naval chiefs). aircraft type: BF 109 (carrier); Ju 87B, Fi 167 or Ar 195; Ar 196.

Squadron (Staffel) = 12 aircraft, except for first fighter formations, which are to be increased to 18 aircraft per squadron.

signed Jeschonnek'

Proposed budget 1939/40, dated February 1939

Technical development

Aircraft development:	
Combat, transport, and special aircraft	47,000,000
Fighter and reconnaissance aircraft	25,000,000
Seaplanes	22,000,000
Aircraft materials	1,500,000
Undercarriages, de-icing equipment, accessories	1,000,000
Gliding equipment	345,000
New developments in airships	1,000,000
Experiments in materials	100,000
	97,945,000
Engine development:	
Liquid-cooled engines	30,000,000
Air-cooled engines	25,000,000
Engine systems	6,000,000
Accessories	1,300,000
Fuels	2,000,000
Tools and semi-finished products	2,500,000
Propellers	3,700,000
Special propulsion systems (LC 3/7)	10,000,000
	80,500,000
Fixed weapons and ammunition:	
Aircraft guns	2,045,000
Mounts and remote control systems	2,095,000
Sights, ballistics	745,000
Installation of towed targets	450,000
Ammunition and fixed guns	3,450,000
Light and signal ammunition	420,000
Armour, protection against guns and fire	3,015,000
Special combat measures	390,000
Fuses and fuse systems	445,000
Chemical weapons	1,150,000
Bombs and bomb transport systems	2,600,000
Bomb-aiming devices and ballistic equipment	905,000
Bomb release apparatus	2,480,000
Torpedo development	400,000
Firing range extensions	860,000
	21,450,000
Aircraft equipment:	
Flight and engine monitoring equipment	2,500,000
Camera equipment	460,000
Safety apparatus	650,000
Aircraft electricity and energy supplies	1,500,000
Gyro and control equipment	4,600,000
Aircraft communication and navigation equipment	15,860,000
Radio navigation, etc.	9,000,000
Telephone equipment	700,000
	35,270,000
Total sum	235,165,00

Fighter/Destroyer Development after the Munich Agreement

Four weeks after the 'saving of peace', on 30 October, 1938, Engineer General Reidenbach, head of the LC II Division of the Air Ministry, paid a visit to the firm of Arado. In a discussion with the technical director, Walter Blume, and his three closest colleagues in the aerodynamics and design departments, he began as follows: This time we have got away with it, but Tommy will be after us next autumn. The 109 is a good fighter, and we are well equipped in that department. But the 110 is not what it should be. It is not fast enough, and the defensive armament is too weak, especially downward. We need a new destroyer. You and Messerschmitt are to build one each. Messerschmitt is to take the conservative route. You (Arado) can take more risks. But we must have the aircraft in twelve months' time.'

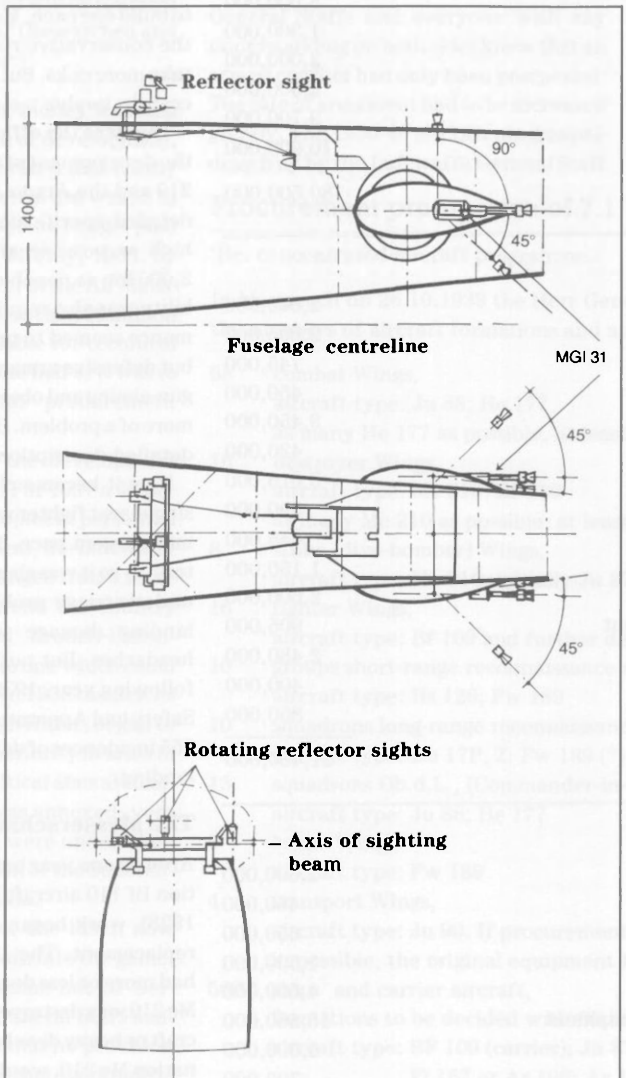
That was the official starting signal for the development of the Messerschmitt Me 210 and the Arado Ar 240. There was no detailed specification. Simply: speed as high as possible and range as close to 2,000 km as possible. Dive-bomber capability was also required. Altitude performance seemed to present no difficulties, but defensive armament and the requisite gun-aiming and observation facilities were more of a problem. But more on this in the detailed description of both aircraft.

Now it became clear why the Fw 190 single-seat fighter was not developed at a more urgent pace. The 109 was satisfactory, or so it was claimed, even though the undercarriage problem and consequent landing damage were giving serious headaches. But nothing changed; in the following year, 1939, the Chief of Flight Safety and Apparatus reported more than 255 incidences of damage to the Bf 109 on landing.

The Messerschmitt Me 210[20]

Around one year before the first production Bf 110 aircraft were delivered (July 1938), work began in the factory on its replacement. The Luftwaffe leadership had more or less decided already that the Me 210, or a destroyer and light combat aircraft or heavy dive-bomber with the designation Me 210, would be introduced. The formations required in the Luftwaffe General Staff's procurement programme of 7 November, 1938, aiming at 1 April, 1942, were as follows (based on 3 squa-

Messerschmitt Me 210. First version with split flaps and twin fins.



Messerschmitt Me 210 weapons and sighting system.

drons per group, and 3 groups per wing):

Light fighter formations
around 3,000 aircraft

Heavy fighter formations
around 3,000 aircraft

Dive-bomber formations (inc. Ju 87)
around 2,000 aircraft

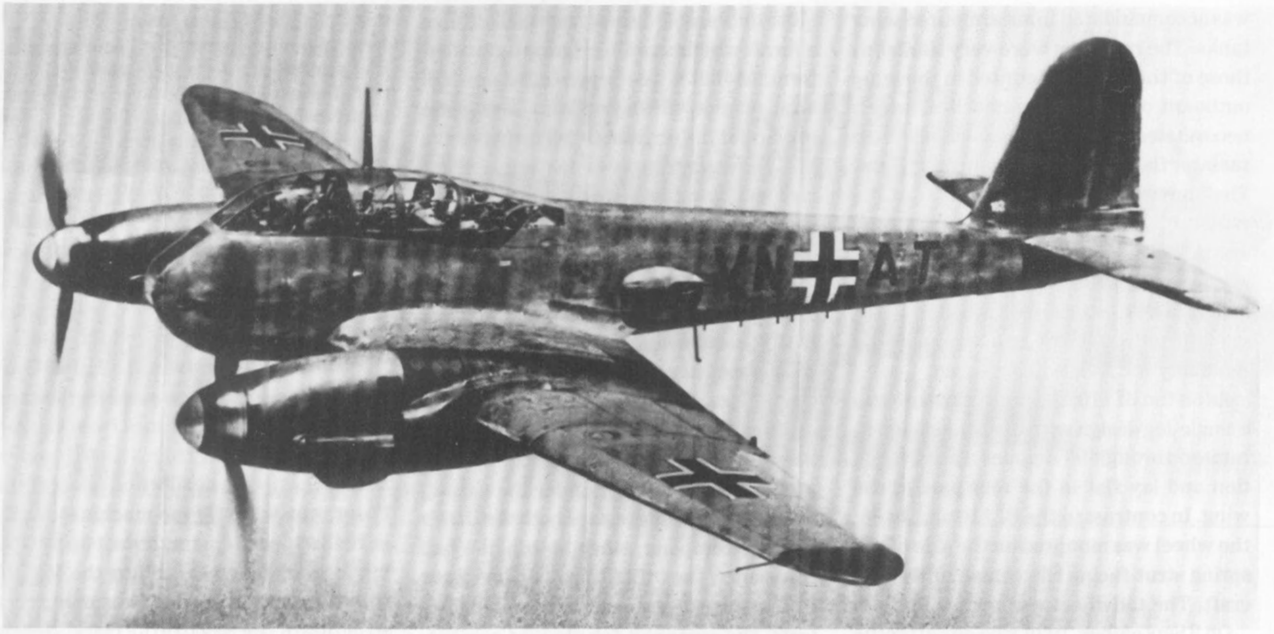
The main part of the destroyer/dive-bomber force, around 3,000 aircraft, was to consist of the Me 210, an aircraft which was not due to fly for a further year.

The dimensions of the Me 210 did not appear to differ substantially from those of the Bf 110 which it was to replace. An improvement in performance could not be expected, unless an enlarged fuel load produced an increase in range, but this would inevitably increase all-up weight, which in turn would increase the airframe weight because of the strengthening required.

Messerschmitt installed a larger calibre weapon, the MG 131 machine-gun, to meet the demand for improved defensive capability, especially downward to the rear. The guns, mounted in a drum on each side of the fuselage, could be rotated up and down in parallel, and could be aimed separately to right or left. However, the servo control system could only direct one side at a time.

In order to provide a good view down and to the side, the radio operator/tail gunner's Plexiglas canopy projected far out over the rear fuselage so that the gunner could lean overboard, so to speak, inside the cabin. The rear section of the Plexiglas canopy was made of plano-parallel glass sheets, through which the gunner aimed the weapons via a servo control system, using one of three reflex sights, one for left, one for right, one for centre.

In order to provide a good view for the



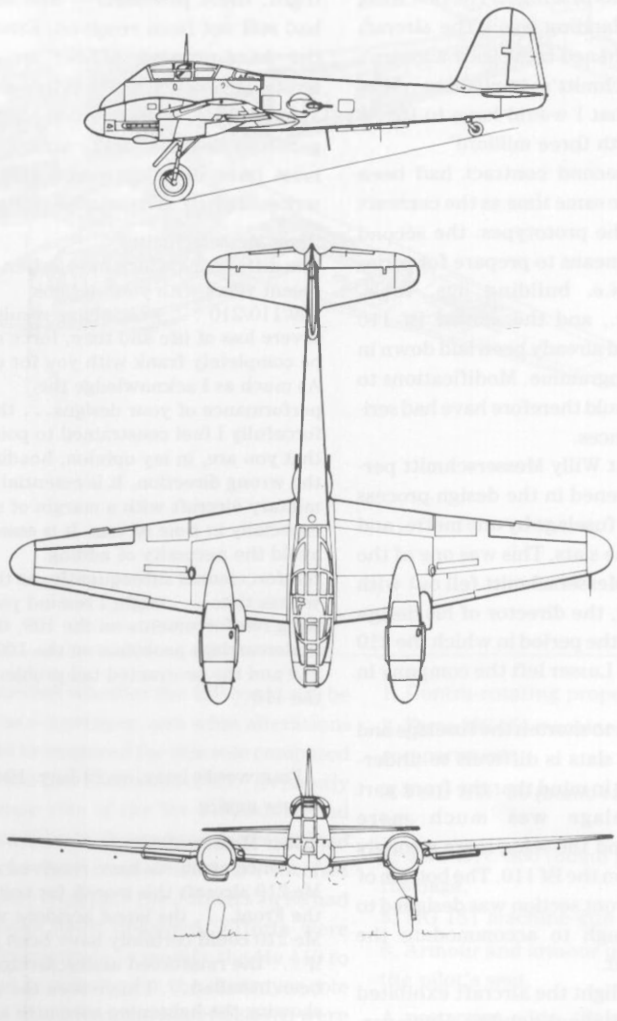
crew, the cabin area was very broad, but the fuselage had a pronounced taper to the rear fuselage, which was of relatively small cross-section. The fuselage was built as right and left shells which were riveted together after fitting out, in a similar fashion to the 109 and 110.

The wing was a three-part structure with a single spar. The outboard panels were attached to the centre section just outboard of the engine nacelles at three points: spar top flange, bottom flange, and leading edge. The centre-section spar continued through the fuselage. The engine forces were transferred to a nacelle design which was securely integrated into the wing structure, and which also carried the undercarriage.

The engine mountings were welded sheet steel box structures, instead of the pressed magnesium mountings favoured by the Ministry. It was Rethel, who had moved from Arado to Messerschmitt, who made this decision, as he was worried that the few large presses available could be paralysed by enemy air attacks.

The internal fuel (2,500 litres — 1,850 kg)

Messerschmitt Me 210, modified version with single fin.



Messerschmitt Me 210

Wingspan	16.35 m
Length	12.55 m (11.65 m)
Wing area	36.2 sq m
Equipped weight	7,070 kg
All-up weight	9,460 kg
Two Daimler-Benz DB 601F	1,190 hp at 5,900 m

was accommodated in six armoured wing tanks. The radiators were very similar to those of the Bf 110, mounted in the wing outboard of the engine nacelles, which necessitated a similarly complex combined radiator flap/landing flap control system. The uneven speed distribution aft of the radiator led to poor radiator efficiency, and in an attempt to improve this a boundary layer channel was fitted over the radiator. Willy Messerschmitt himself explained this feature in a lecture to the Acadamy for Aviation Research.

As on the Bf 110, the undercarriage was a single-leg design with one wheel, which rotated through 90 degrees upon retraction and lay flat in the rear part of the wing. In contrast to the Bf 110 and Ju 88, the wheel was mounted on the side of the spring strut facing the centre of the aircraft. The tailwheel was retractable.

On 2 September, 1939, one day after the start of the war, Hermann Wurster piloted the aircraft on its first flight. The first thing he said after landing was: 'The aircraft must be lengthened by at least a metre'. And Messerschmitt's immediate reply was: 'To do that I would have to throw away jigs worth three million!'

In fact, a second contract had been awarded at the same time as the contract for building the prototypes: the second provided the means to prepare for series production, *i.e.* building jigs, tools, materials, etc., and the end of Bf 110 production had already been laid down in the overall programme. Modifications to the aircraft would therefore have had serious consequences.

It is said that Willy Messerschmitt personally intervened in the design process to shorten the fuselage by one metre, and to leave out the slats. This was one of the reasons why Messerschmitt fell out with Robert Lusser, the director of his design office, during the period in which the 210 was designed. Lusser left the company in March 1939.

The decision to shorten the fuselage and leave out the slats is difficult to understand, bearing in mind that the front part of the fuselage was much more voluminous and the wing more strongly tapered than on the Bf 110. The bottom of the fuselage front section was designed to be wide enough to accommodate the bombs inboard.

On its first flight the aircraft exhibited a lack of longitudinal stability. However, the worst fault was that it swung from side to side around the vertical (yaw) axis to a quite intolerable extent, especially for an aircraft which was meant to be a gun platform. At first it was hoped that a new tail arrangement, with a very large, central fin in place of the original twin fins (as on the Bf 110) would improve matters. In any case the twin fins did not fit in well with the weapons arrangement. A new larger tailplane was also fitted. There followed a long, tedious series of tests, during which all manner of experiments were made, all with the same aim of avoiding the really crucial step of a major airframe modification. Minor changes were made to every possible component. The problems, or more precisely any knowledge of the problems, were swept under the carpet. This was in the interests of both the Office and the company, since both had a bad conscience: the Office because it had made a premature decision without making any tests; the company for obvious reasons. When, almost two years after the first flight, these problems — and others — had still not been resolved, Ernst Udet, the hard-pressed officer in charge, wrote Messerschmitt a letter dated 27 June, 1941. To Udet, a companionable, generous-hearted, polite man, the letter must have been extremely difficult to write. Slightly abbreviated, it runs:

'Dear Messerschmitt,
The difficulties which have arisen in recent years with your designs 109/110/210 . . . which have resulted in severe loss of life and time, force me to be completely frank with you for once . . . As much as I acknowledge the performance of your designs . . . the more forcefully I feel constrained to point out that you are, in my opinion, heading in the wrong direction. It is essential to design military aircraft with a margin of safety, especially in time of war. It is essential to avoid the necessity of adding reinforcements subsequently, as this wastes time . . . might I remind you of the wing reinforcements on the 109, the undercarriage problems on the 109 and 210 and the protracted tail problems with the 110 . . .'

Four weeks later, on 29 July, 1941, Udet wrote again:

'(Dear Messerschmitt,)
. . . Once again we have received no Me 210 aircraft this month for testing at the Front . . . the latest accident with the Me 210 could certainly have been avoided if . . . the reinforced undercarriage had been installed . . . I have seen the drawing showing the lightening measures applied to the undercarriage, and was astounded to see that this weakness resulted from a weight saving of 3.5 kg . . . Let us get one thing completely clear, dear Messerschmitt: it must not occur again that aircraft are destroyed when flying from normal airfields because of an insufficiently strong undercarriage . . . All these unnecessary irritations . . . force me to institute a more stringent checking procedure on your new designs . . .'

But Udet had no chance to carry out his threat. He was called to account for these and other even more serious failures, and he broke down under the strain and committed suicide on 17 November, 1941.

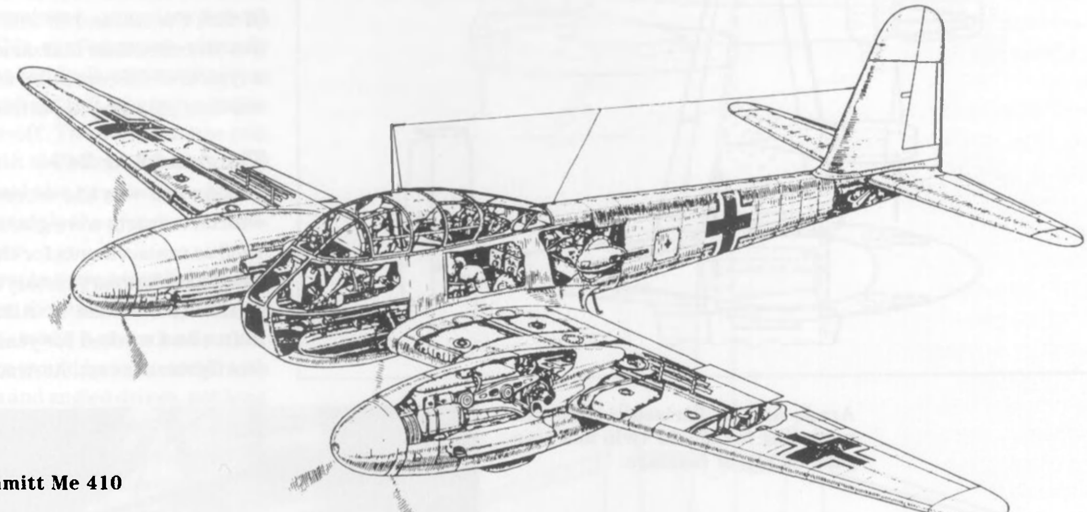
A total of thirty-seven Me 210 aircraft took part in the test programme: sixteen prototypes, eight machines from the A-0 series and thirteen from the A-1 series. Matters came to a head when pilots at the Front refused to fly the machines. Early in 1942 a special committee set up by Goring recommended cancelling the Me 210 from the programme, and resuming construction of the Bf 110 in its place. Goring discussed the matter with Messerschmitt on 9 March, and made the official decision on 14 April, 1942, two and three-quarter years after the machine's first flight. At the same time he demanded Messerschmitt's resignation from the company. But: *Deus ex machina*, a few days before this the Me 210 V17 flew. The tail extension, which had been recommended immediately after the first flight, had been made, and lo and behold, here was an aircraft with acceptable flying characteristics. The slats, added shortly before, also proved to be helpful.

The following measures had proved necessary before the aircraft found its final form:

1. Central fin instead of twin fins,
2. Tail length from centre of gravity to fin increased by around one metre,
3. Automatic slats fitted,
4. Dive-brakes moved from underside of wing centre section to underside of outboard panels, then to top and bottom surfaces of outboard panels, finally completely redesigned,
5. Landing flaps modified from split flap to slotted flap,
6. Fuselage cross-section at the rear virtually doubled and skin reinforced.

The Messerschmitt Me 410

Hurriedly the assembly lines were set into motion again and a series of Me 210s was built. However, it was now late summer 1942 when the machines arrived at the Front instead of early 1941, as had been planned in 1938. By this time the aircraft



Messerschmitt Me 410

Wingspan	16.35 m
Length	12.50 m
Equipped weight	7,525 kg
All-up weight	9,660 kg
Two Daimler-Benz DB 603A	1,625 hp at 5.700 m

proved to be too slow for use in the West. It was hoped that more powerful engines would make up the difference in performance; first the DB 605 producing 1,360 hp at 7,500 m altitude, and later the DB 603 producing 1,625 hp at 5,700 m. The aircraft with the DB 603 motors were renamed the Me 410.

As was to be expected, the aircraft's stability suffered when the more powerful engines were installed. A memorandum written by the commander of testing stations dated 12 November, 1941, runs as follows: 'The purpose of the discussion was to establish whether the 410 could still be used as a destroyer, and what alterations would be required for this role compared with the fast combat aircraft.' Evidently the main role of the Me 410, which had originally been planned as a destroyer, had become 'fast combat aircraft', *i.e.* fast bomber, for which the Junkers Ju 88 had originally been designed. Efforts were now being made to modify the Me 410 to render it suitable for the destroyer role again. The following modifications were demanded:

1. Contra-rotating propellers,
2. Three MG 151 machine-guns in the bomb compartment,
3. Four ETC 50 (bomb racks) in the floor bay,
4. Two ETC 500 (bomb racks) under the fuselage,
5. MG 151 machine-gun set,
6. Armour and armour plating in front of the pilot's seat.

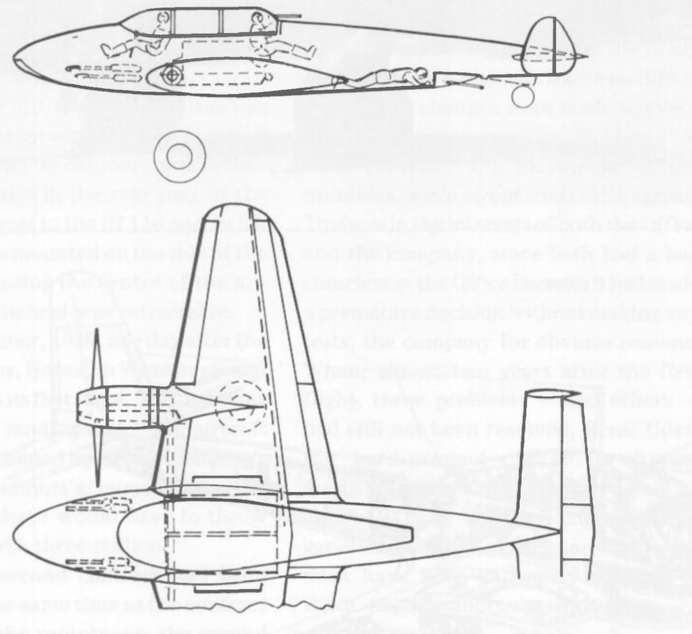
A postscript adds: 'Take-off and flying characteristics of the Me 410 fitted with the DB 603 are worse than the 210 with

the long fuselage, but nothing like as bad as the Me 210 with the short fuselage.' This was the reason why contra-rotating airscrews were called for, as they would lessen the de-stabilising effect of the propellers.

Scarcely had the aircraft been developed into a reasonably reliable machine, than flying crews set about 'improving' it with extra fittings, both external and internal. A discussion amongst the General Staff 6th division, dated 16 August, 1943, called for the installation of a KWK 39/I 50 mm cannon. Some months later the weapons, which at the time existed in prototype form only (no preparations had been made to produce them in series), had been procured after considerable difficulty and installed in the aircraft. On 12 May, 1944, at 13.26 hr a formation of Me 410s fitted with 50 mm cannon was used against 50 to 60 Boeing B-17 Fortresses flying without fighter escort. 'In eight aircraft the cannon failed after the first few shots. Nine aircraft (35 per cent) did not return, nothing is known of the rate of cannon failure in those cases.'

In a discussion at LC II the General of the fighter pilots demanded the rocket-propelled grenade 21[21] as standard equipment for the Me 410, as well as for the Bf 109, Fw 190 and Bf 110. The demand was cancelled later that same day. But this is typical of the confusion which reigns in wartime planning departments.

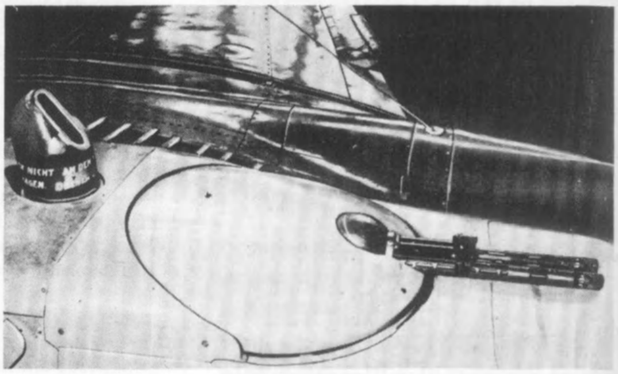
Arado project E 651, a destroyer with upper and lower defensive armament. Three-man crew.



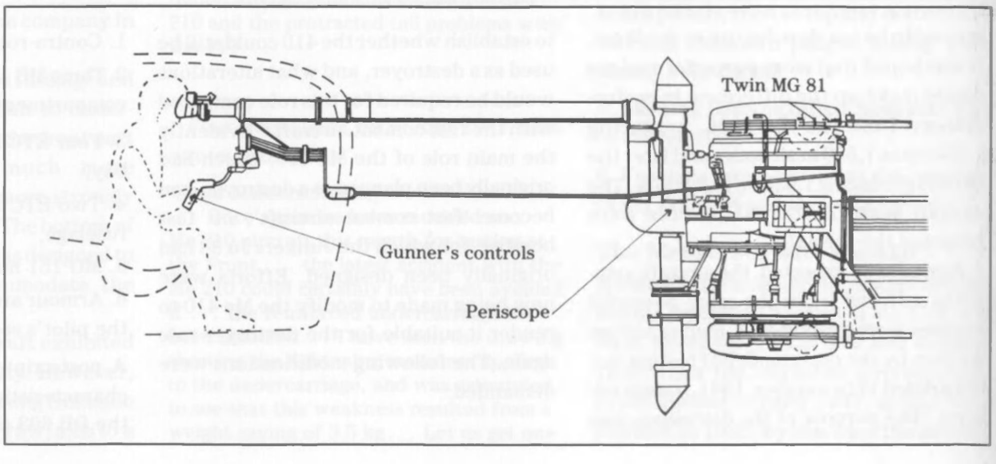
The Arado Ar 240

The Ar 240 was the second aircraft for which contracts were granted in autumn 1938 as replacements for the Bf 110, and it had a preliminary history similar to that of the 210. Whilst at Albatros, Walter Blume had worked for years on the two-seat fighter concept. At Arado he resumed

Arado Ar 240. Periscope sight and mounting for MG 81 twin machine-guns on top of fuselage.



Arado Ar 240. Weapons and sighting installation.



work on the idea of a fighter with rearward defence. He attempted to find a concept which combined several features: maximum flying performance, maximum safety with one engine dead, effective rearward defence, and heavy forward armament. The result was a design with two Daimler-Benz DB 601 engines side by side in the fuselage, with the pilot and bomb aimer in front of them, one slightly in front of the other. One defensive gunner was located in a seated position at the rear of the cockpit, and a further one lay prone on the floor. The two propellers were mounted on the wings, as on a conventional twin-engined design, but they were both driven by both motors via a common gearbox and remote shafts with right-angle gearboxes. If one motor should fail, the remaining one drove both propellers. This configuration virtually eliminated the highly dangerous situation in twin-engined aircraft when one engine failed on take-off. The performance gain compared with the drag of a stationary propeller would also have been considerable. Unfortunately the system was complex and heavy.

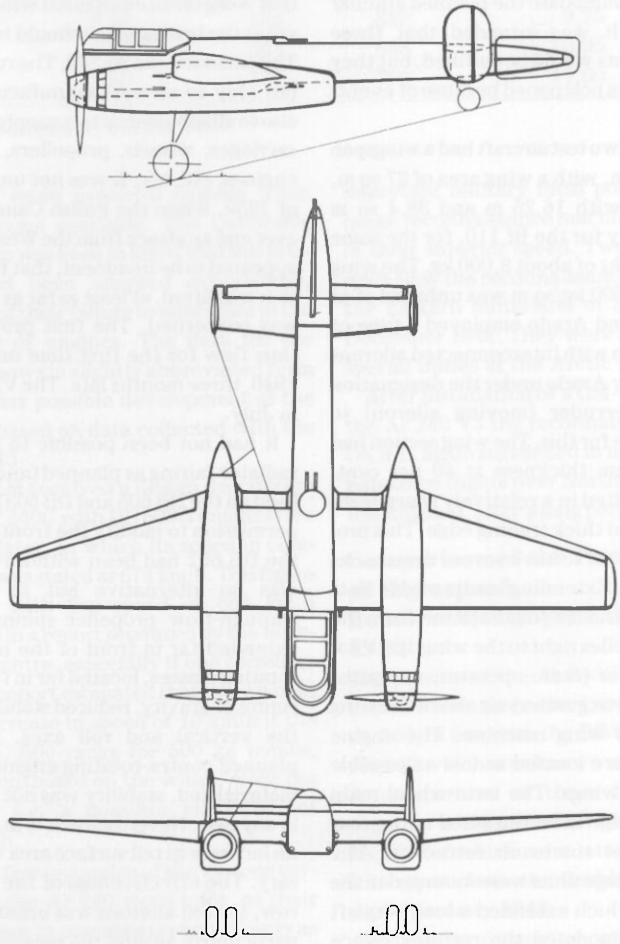
When contracts were awarded for the new destroyer, the chief of LC II, Aircraft Development, made it abundantly clear that the Office would have no truck with remote shafts and angled drives, not least because development time was short; what was required was a conventional aircraft with two 'normal' power plants located in front of the wings, and flown by a two-man crew.

The Ar 240 Defensive System. In the discussions which followed on possible aiming techniques for the rearward-facing weapons I suggested the use of a periscope. This did not require much imagination. In the college holidays in 1930 I had worked as a designer in the Geo division of Zeiss, at Jena, where I had had the opportunity to use a periscope. The potential for gun aiming immediatley struck me, and the result was the concept of the Ar 240's defensive system.

The company of Goerz found no difficulty in designing the optical system, but the mechanism for driving the annular rotary gun mounts and transferring the sight (periscope) position to the weapons gave many problems. We made many false starts before a satisfactory solution was found, with the help of a whole series of remote control specialists and companies. Unfortunately this took nearly three years, and the lost time contributed greatly to the discrediting of the periscope principle. The remote drive system for the Messerschmitt three-reflex sight system was destined to undergo a similarly difficult and protracted development process.

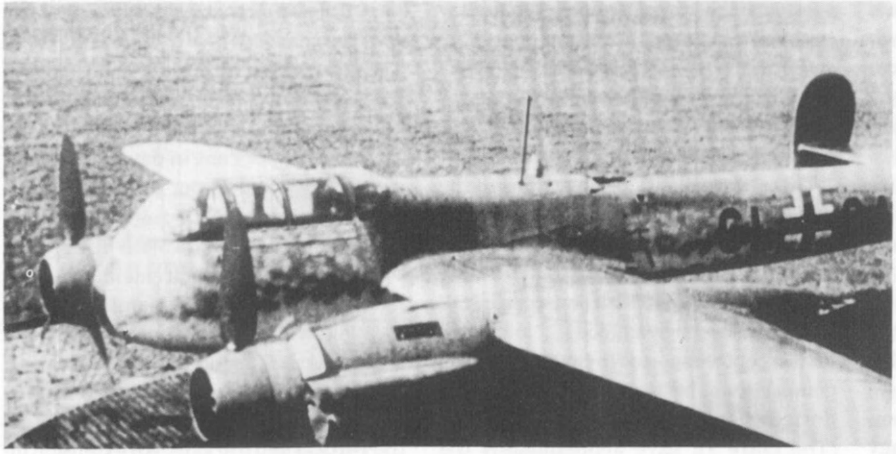
There were plenty of objections to the periscope, but a report by Long-distance Reconnaissance Group 100 dated August 1943 runs as follows: 'The squadron has found the Arado 240 with periscope installation outstandingly as good . . .' and Rechlin test centre reported in October 1944 on comparisons between various aiming devices, especially at dusk and at night: 'The Lotfe 7E gave approximately the same range in all conditions as the unaided eye; the periscope was at least as good . . . The reflex sight with the armoured glass screen gave average sighting range, but when compared with the periscope it was worse by 10 per cent in daylight, 20 per cent at dusk and 35 per cent at night.'

The Ar 240 Airframe. With due regard to the contractual requirement for maximum speed, Arado put immense effort into creating an aircraft with minimum surface area and cross-sections. Contra-rotating propellers were a requirement from the outset, in the interests of stability around the vertical and roll axes. An extension of



Arado Ar 240A-O

Wingspan	14.3 m
Length	11.9 m
Wing area	31.0 sq m
Empty weight	6,200 kg
Equipped weight	7,290 kg
All-up weight	9,460 kg
Two Daimler-Benz DB 601E	1,200 hp



Arado Ar 240 V3, the version with the DB 601 engines, which was built as the 0-series.

the gearbox front structure was also called for, to accommodate the planned annular radiators. It was intended that these requirements would be fulfilled, but they were always postponed because of events in the war.

The first two test aircraft had a wingspan of only 12 m, with a wing area of 27 sq m, compared with 16.25 m and 38.4 sq m respectively for the Bf 110, for the same all-up weight of about 8,000 kg. The wing loading of 300 kg/sq m was unheard of at the time, and Arado employed a type of Fowler Flap with interconnected ailerons patented by Arado under the designation Wanderquerruder (moving aileron) to compensate for this. The wing section had its maximum thickness at 40 per cent, which resulted in a relatively sharp leading edge and thick trailing edge. This profile turned out to have severe drawbacks in practice. Extending leading-edge slats coupled to the landing flaps ran from the engine nacelles right to the wingtips. Pilot and observer (radio operator, navigator and defensive gunner) sat above the wing of this low-wing machine. The engine nacelles were located as low as possible under the wings. The twin-wheel main undercarriage units retracted to the rear and did not rotate on retraction. The under-carriage units were mounted in the nacelles, which extended a long way aft and accommodated the reconnaissance cameras behind the wheels. There was no room on the small wing for an adequately effective dive-brake. A brake parachute was housed in the tail of the aircraft aft of the surfaces.

The mock-up had been inspected on 31 March, 1939, and in autumn the same year the prototype was three-quarters complete when, on 1 September, 1939, the first day of the war, and ten months after the contract had been granted, the chiefs of the armed forces or the Luftwaffe decided that work on all equipment which was not yet at the testing stage should be stopped. This included the Ar 240. The rule applied not only to aircraft manufacturers, but also to all sub-contractors supplying undercarriages, wheels, propellers, radiators, engines, etc, etc. It was not until the end of 1939, when the Polish Campaign was over and an attack from the West no longer appeared to be imminent, that this restriction was lifted, at least as far as the Ar 240 was concerned. The first prototype V1 thus flew for the first time on 30 April, 1940, three months late. The V2 followed in July.

It had not been possible to install the radiator fairing as planned (and later realised on the DB 605 and DB 603) as official permission to modify the front section of the DB 601 had been withdrawn. There was no alternative but to construct through-flow propeller spinners which extended far in front of the hub. These rotating masses, located far in front of the centre of gravity, reduced stability around the vertical and roll axes. Since the planned contra-rotating engines had not materialised, stability was not very good in any case. Nevertheless it was found that no increase in tail surface area was necessary. The effectiveness of the long, narrow, slotted ailerons was unsatisfactory, particularly around the neutral position. The problem was caused by the wing profile and the resultant large included angle of the trailing edge, but this was only discovered later during wind-tunnel tests. Thickening up the trailing edge helped, and in this form the aircraft was delivered to the Rechlin Centre for test flying. This was in the summer of 1940.

Optimism after the Victory in the West. Here we must fit in a few words about the general situation at the time. After the unexpectedly rapid victory over France the anxiety which had plagued the minds of ordinary people and leaders made way for optimism. There was talk of cutting back on armaments, and plans for peacetime conditions were drawn up. The technical director of Arado held a discussion with his leading colleagues, and presented them with his plans for a range of civil aircraft, instead of discussing further work on the Ar 240. I objected twice on the grounds that what Germany needed was improved, faster combat aircraft, but my comments only angered the other participants. The director of the engine division was called in to the meeting, and he reported on a visit he had made to the firm of Continental in Hanover the previous day. There everything was said to be changing back to peacetime conditions. It must have been the same in the other aircraft firms, otherwise there is no explanation for the slow progress in the development work on the fighter/destroyer projects. This optimism was maintained long after the air attacks on the British Isles had ended in failure, but this was due, of course, to the propaganda, which was supplied to everybody—not only to the great mass of ordinary people.

The immense effort which went into setting up large volume production of aircraft, beginning in the autumn of 1940, was claimed to presage an attack on Britain. It would have caused great public discord, if nothing worse, to speak openly of the possibility of Germany becoming entangled with the USSR and an unending expansion of the war. However, on 9 February, 1940, Göring ordered that all work which was aimed at the postwar period was to be stopped, and his order met with no official countermand.

Performance estimates for aircraft to be developed from the Ar 240, July 1941

Engine	Combat power at sea level (kW/hp)	Full pressure at altitude (kW/hp)	Full pressure at altitude (m)	Weight (kg)	Wingspan (m)	Wing area (sq m)
DB 601E	880/1200	880/1200	4,900	9,600	14.2	31
DB 605B-4	955/1300	920/1250	5,800	9,700	14.2	31
DB 605C-3	1000/1350	955/1300	5,800	9,700	14.2	31
DB 603B-4	1140/1550	1120/1530	5,100	10,500	16.2	35
DB 603C-3	1210/1650	1180/1600	5,800	10,500	16.2	35
DB 614*	1230/1810	1130/1530	8,700	10,700	16.2	35

Engine	Wing loading	Power loading		Maximum speed		Service ceiling
	(kg/sq m)	(kg/kW)	(kg/hp)	sea level	6,000m	(m)
DB 601E	310	2.94	4.0	513	631	8.75
DB 605B-4	313	2.85	3.88	529	642	9.45
DB 605C-3	313	2.76	3.76	535	655	
DB 603B-4	300	2.52	3.42	550	680	9.75
DB 603C-3	300	2.41	3.28	563	695	10.35
DB 614*	306	2.57	3.50	577	703	11.60

* The DB 614, planned to produce 1,500 kW, 2,020 hp take-off power, was not built.

Further Development of the Ar 240. It is very likely that the new destroyer requirements came about because of the realisation that the Bf 110 destroyer had not fulfilled official expectations in service in the West. The modifications called for were as follows:

1. Full-view cockpit allowing the pilot to see 60 to 65 degrees forward and down; both crew members to be located forward of the wing leading edge,
2. Pressurised cabin,
3. More powerful defensive armament.

The result of this was a layout which differed substantially from the first prototypes V1 and V2. Moving the cabin forwards required that the engines were shifted forward, as it was not considered desirable to locate the pilot in the plane of the propellers. The resultant forward shift of the centre of gravity, and the destabilising effects around the vertical and roll axes, could only be countered by extending the tail. The result was an aircraft which was about one and a half metres longer; in order to preserve the levels of performance and flying characteristics the wingspan was also increased by a little over two metres. The rectangular wing centre section was retained. In the interests of eliminating the icing problem, the leading-edge slats were abandoned in favour of a modified wing section and a fixed leading edge. The wing leading edge was now straight over its entire length.

Measures had to be taken to allow installation of more powerful engines when they became available. The Luftwaffe leadership was keen to know that this principle had been adopted everywhere, because of their failure to anticipate in the planning of engines. The data for the Ar 440 shows in slightly abbreviated form the further possible development of the Ar 240, based on data collected with the Ar 240 V3.

The RLM received a design description of the Ar 240C with DB 603A engines five months later, in which its speed in combat trim was stated as 674 km/h. This figure concurs with the speed of 661 km/h included in a report produced by the Rechlin test centre, especially if one considers that the report estimated that there would be an increase in speed of 10 km/h if the two ETC 500 racks for 500 kg bombs, located outboard on the wings, were not fitted[22] *i.e.* a possible maximum of 670 km/h.

Only a few examples of the various versions of the Ar 240 were built, as their importance in planning terms was only as an emergency substitute for the Me 210. A zero series which was built at the Ago works in Oschersleben was halted shortly after it had started; only five aircraft were completed. This occurred when the handling problems of the Me 210, an aircraft already in large-scale production, were finally solved. Not one of the test and zero series machines was lost in a flying accident. All of them, apart from the V1 and V2 prototypes, saw operational service at important military focal points as long-range reconnaissance machines, because of their superior speed. Two Ar 240 aircraft flew the reconnaissance missions in the Eastern hinterland of Stalingrad in December 1942. They were also used for special duties at the Arctic Front.

After installation of a GM-1 system[23] in the Ar 240 V3 the reconnaissance group Ob.d.L. again succeeded in making reconnaissance flights over Northern and Central England, after a long period of failure.

Comparison of the Performance of High-speed Bombers/Destroyers, January 1943

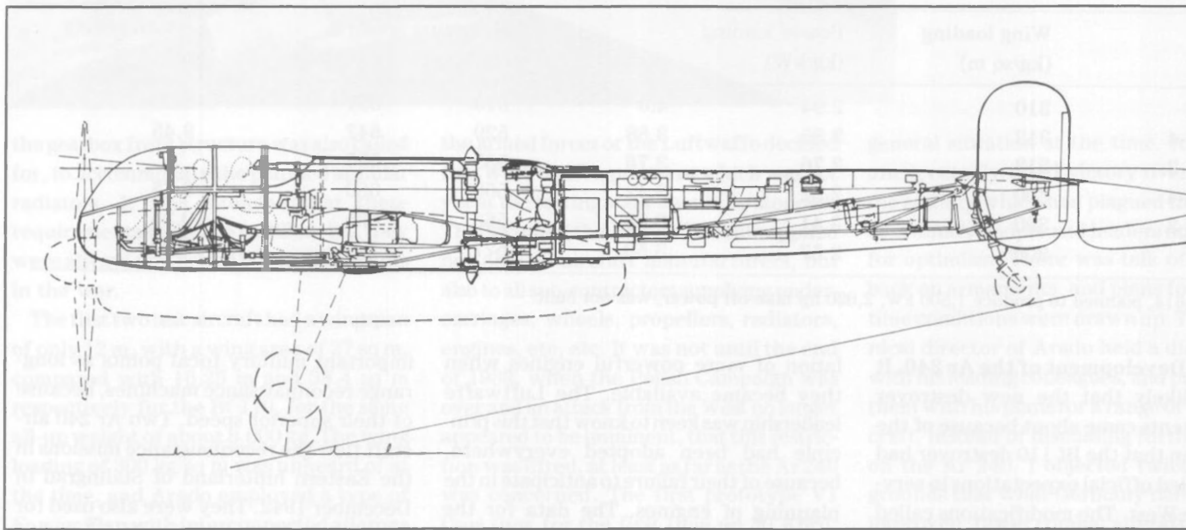
The version of the Ar 240C with DB 603 engines was given the type designation Ar 440, in line with the DB 603-equipped Me 210 which was known as the Me 410. A comparison of these two aircraft, together with the Junkers Ju 88S and the He 219 (of which more later), is included in a report from the Rechlin test centre dated January 1943:

'Fast bomber comparison with two 500 kg bombs
Me 410, Ar 440, Ju 88, He 219
summary (abbreviated)
. . . Me 410 and Ar 440 prototypes were measured. Figures for the Ju 88S were converted from values obtained with the 88. The He 219 performance figures are projected values, which should be obtained if the machine is built accurately. Based solely on the figures shown — V_{max} in combat trim, range and altitude, continuous power — the Ar 440 has a clear advantage.'

In our discussion on the development of the destroyer — an aircraft type which was considered more or less as a heavy fighter in 1938, but was later called upon to play the part of long-distance reconnaissance aircraft and fast bomber — we find ourselves in the midst of the war. Contrary to all the plans, final development of these aircraft did not take place until the war was in progress.

Type	Me 410	Ar 440	Ju 88S	He 219
Engine	DB 603A	DB 603A	BMW 801D	DB 603A
Target weight without bombs	9,250	10,750	9,900	10,850
V_{max} at altitude	626/6,800 m*	661/7.0	600/8.0	606/6.5
Range at altitude	1,190/6.5	1,590/6.7	935/6.2	?

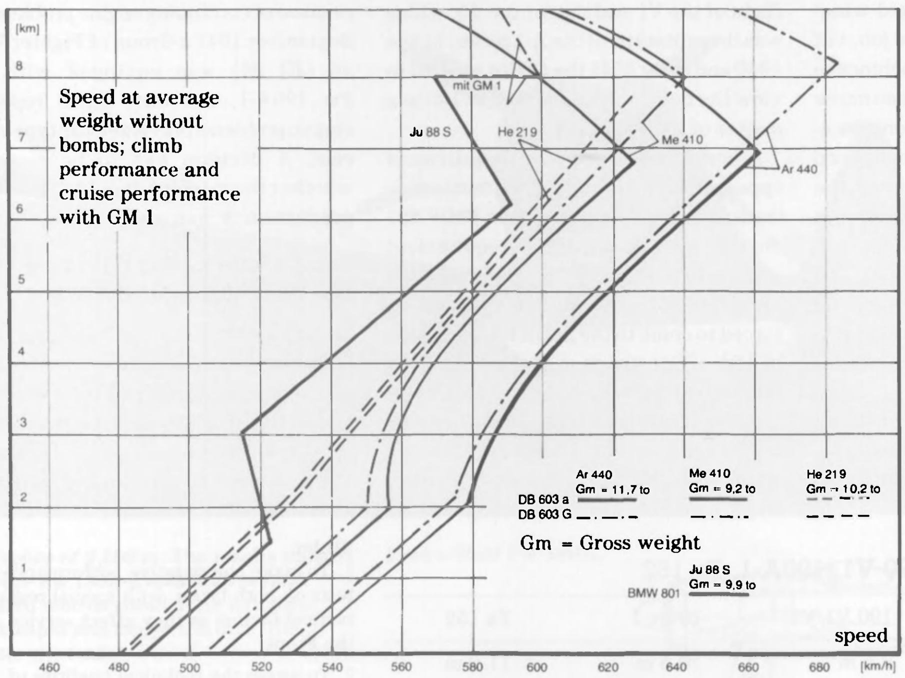
* 'The Me 410 prototype has achieved only 614 km/h at the full pressure altitude of 6,300 m. The planned improvement is to be achieved in Stage II, with the result that the Ar 440 at this time has a speed advantage of 47 km/h.'



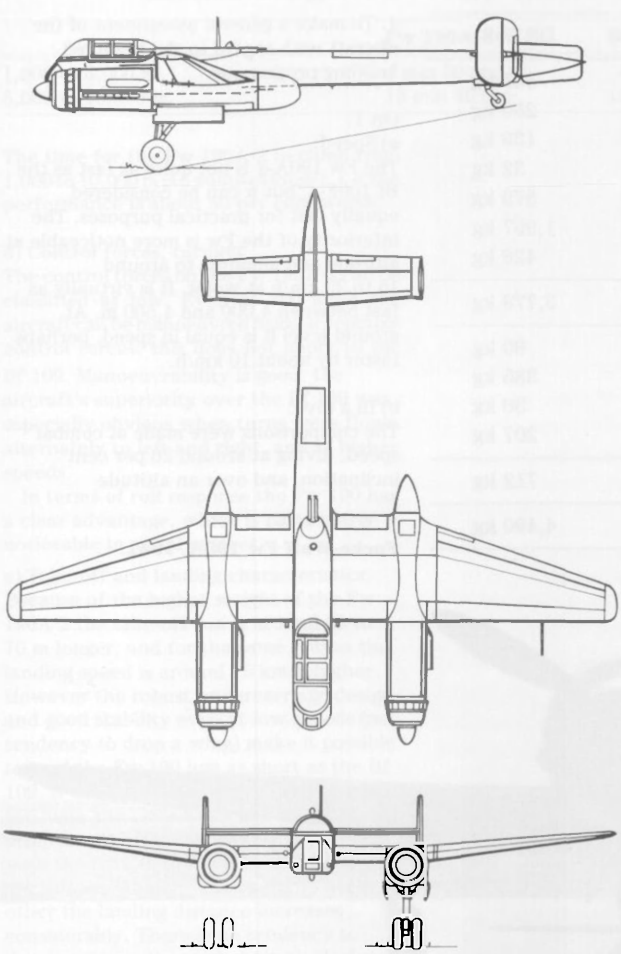
Arado 440 — sectional drawing of fuselage.

Arado Ar 440

Wingspan	16.3 m
Length	14.3 m
Wing area	35.0 sq m
Empty weight	9,200 kg
All-up weight	12,200 kg
Two Daimler-Benz DB 603	1,560 hp at 7,400 m



Performance comparison for fast bomber/destroyer aircraft. As at January 1943.



Arado Ar 440

Further Development of the Fw 190 and Bf 109F

The single-seat fighters underwent a similar process. The Fw 190, which has already been mentioned briefly, had a difficult start after it first flew on 1 June, 1939. Three V-aircraft were built, one of them for testing to destruction. The engine for which the aircraft had been designed — the BMW 139 — was abandoned when the firms of Bramo (Brandenburgische Motorenwerke) and BMW (Bayerische Motoren Werke) merged. A new power plant of similar size, the BMW 801, took its place. Although it had not been fully tested, it was installed in the V5[24], which completed its first flight with the new engine in summer 1940. The BMW 801 was 190 kg heavier than the BMW 139. The extra weight, together with the necessary reinforcements, etc., necessitated an increase in the size of the wing: 10.5 m wingspan and 18.3 sq m wing area instead of the original 9.5 m and 15 sq m. The larger wing was less highly tapered than the original, which was certainly beneficial to the aircraft's stalling behaviour. Contracts to build a zero-series of 28 aircraft, together with the two prototypes *i.e.* 30 machines, had been awarded a long time previously, and the first seven machines were therefore built with the smaller wing, the

remainder with the larger.

The simple statement 'enlarged wing' might indicate a straightforward job, but in fact modifying the first V-machines to the production specification was no minor undertaking. For example, the centre section of the wing, which had originally been a stressed-skin design running through the fuselage, was abandoned in favour of a spar structure. The following table indicates the extent of the modifications. The table also includes the corresponding values relating to the Ta 152, which was one of the high-altitude fighters developed from the Fw 190 in 1944.

The increase in engine weight of 192 kg had necessitated an increase in wing structure weight of 104 kg, and the total flying weight had risen by 700 kg.

A whole year passed between the first flight of the V1 and that of the V5, which was the prototype of the A-1 series. In late 1940 and early 1941 the Office seemed to view the development of the Fw 190 as a matter of little urgency.

A much more pressing requirement appeared to be a twin-engined battle zone transport, for which the same BMW 801 engines were planned. This requirement was laid down early in 1941, when it became clear that Germany would be forced to come to the aid of Italian troops in Africa. Construction of the prototypes was well under way when work on these urgently needed machines was halted: the BMW engines were needed for the Fw 190, which had suddenly become top priority. A special test command was set up at Rechlin, but its work made slow progress because of continuing engine problems. In September 1941 a Group of Fighter Wing 26 (JG 26) was equipped with the Fw 190A-1, but once again repeated engine problems prevented the type's success. A decision had to be made on whether the machine should go into mass production or not.

Data and weights, Fw 190 V1, 190A-1, Ta 152

	190 V1/V2	190A-1	Ta 152
Wingspan	9.5 m	10.5 m	11.0 m
Length	8.5 m	8.95 m	10.8 m
Wing area	15 sq m	18.3 sq m	19.5 sq m
Engine	BMW 139	BMW 801	DB 603
Weight of fuselage	148 kg	302 kg	355 kg
undercarriage	207 kg	285 kg	250 kg
tail	90 kg	121 kg	139 kg
control surfaces	31 kg	31 kg	32 kg
wing	347 kg	451 kg	579 kg
engine	1,380 kg	1,572 kg	1,997 kg
equipment	305 kg	415 kg	426 kg
Airframe weight	2,508 kg	3,177 kg	3,778 kg
Crew	90 kg	90 kg	90 kg
Fuel	400 kg	400 kg	385 kg
Oil	30 kg	30 kg	30 kg
Payload	126 kg	155 kg	207 kg
Additional load	646 kg	675 kg	712 kg
All-up weight	3,154 kg	3,852 kg	4,490 kg

Comparative Flight Testing of the Fw 190A and Bf 109F-4

The test station command was ordered to carry out a comparison of the performance and combat suitability of the Fw 190A-2 and Bf 109, which by now had reached the series F-4. The report, dated 10 December, 1941, came to the following (much abbreviated) conclusion:

'Order:

1. To make comparative performance tests on both types, with special regard to tactical factors as they affect service at the Front.
2. To assess the technical qualities of Fw 190-A2 aircraft type based on practical experience.
3. To suggest modifications.
4. To make a general assessment of the aircraft with regard to the intended building programme.

On 1:

a) Speed:

The Fw 190A-2 is not quite as fast as the Bf 109F-4, but it can be considered equally fast for practical purposes. The inferiority of the Fw is more noticeable at altitude and amounts to around 15 to 20 km/h at worst. It is virtually as fast between 4,000 and 4,500 m. At ground level it is equal in speed, perhaps faster by about 10 km/h.

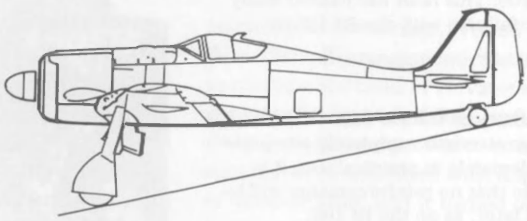
b) In a dive:

The comparisons were made at combat speed, diving at around 20 per cent inclination, and over an altitude

Focke-Wulf Fw 190A, 1941.

difference of 2,000 m. The results showed that the Fw 190A-2 ended up several hundred metres ahead at all altitudes. The steeper and longer the dive, the greater the lead.

Focke-Wulf Fw 190A.



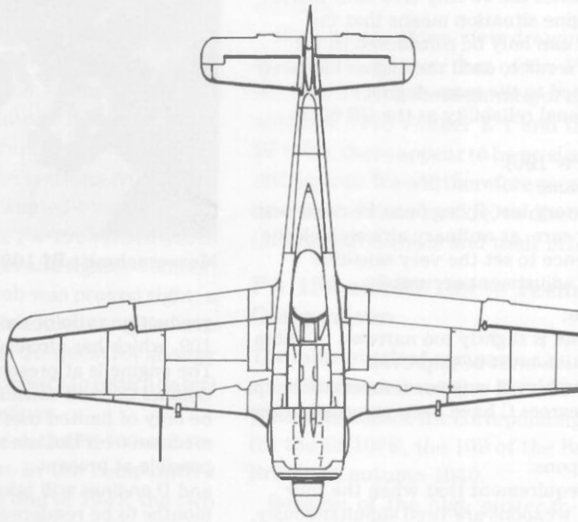
c) In the climb:
The Fw 190A-2 is greatly inferior in climb performance:

	Fw 190A-2	**Bf 109F-4**
1,000 to 5,000 m	4 min 50 sec	4 min
5,000 to 10,000 m	18 min 30 sec	12 min 30 sec

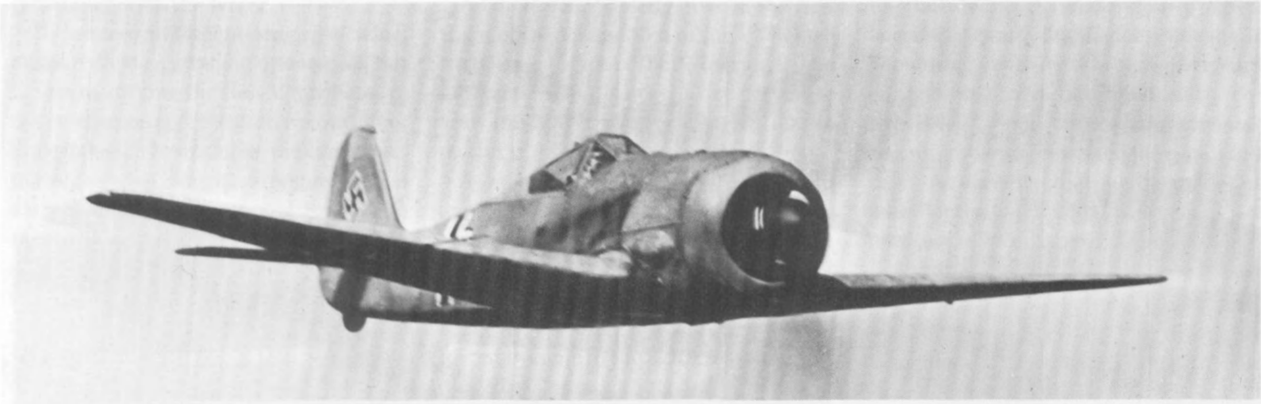
The time for the Fw 190A-2 to climb from 1,000 to 10,000 m is 6 minutes longer, *i.e.* the performance is about 50 per cent worse.

d) Control forces, turning:
The control forces on the Fw 190A-2 can be classified as low. Even at 700 km/h the aircraft can be manoeuvred using acceptable control forces; this does not apply to the Bf 109. Manoeuvrability is good; the aircraft's superiority over the Bf 109 was especially obvious when turns were flown alternately to left and right, and at higher speeds.

In terms of roll response the Fw 190 has a clear advantage, which is particularly noticeable in aerial combat.



e) Take-off and landing characteristics:
Because of the higher weight of the Fw 190A-2 the take-off run is around 60 to 70 m longer, and for the same reason the landing speed is around 15 km/h higher. However the robust undercarriage design and good stability even at low speeds (no tendency to drop a wing) make it possible to land the Fw 190 just as short as the Bf 109. If the approach speed is too low or too high, the error has a more pronounced effect on sinking speed than with the Bf 109: in the one case the aircraft loses height very rapidly, in the other the landing distance increases considerably. There is no tendency to drop a wing at the stall. A particularly noteworthy advantage is that a belly



Focke-Wulf Fw 190A.

landing results in hardly any damage. In no case has the wing or fuselage become distorted, which is regularly the case with the Bf 109. This fault has caused many aircraft failures with the Bf 109 in service.

On 2:
a) Durability of the Fw 190:
Airframe strength completely adequate for all demands in practical use. It is probable that no reinforcements will be needed later, as on the Bf 109.

b) Fw 190 engine:
Experience to date, especially that of JG 26, has shown that the engine must be classified as unreliable and not ready for operational use. The average service life just reaches the twenty-five hour mark. The engine situation means that the aircraft can only be considered fit for limited service, until the engine has been developed to the same degree of operational reliability as the DB 601E.

On 3 (Fw 190):
b) Airframe
. . . Factory test-flying must be done with greater care, as ordinary airmen lack the experience to set the very sensitive aileron adjustment accurately . . .

e) Cabin:
The cabin is slightly too narrow . . . cabin ventilation must be improved considerably; in summer temperatures up to 45 degrees C have been recorded in the cabin.

h) Weapons:
It is a requirement that when the four central weapons are fired simultaneously, the two wing cannon can still be operated separately at any time. It is suggested that the bomb knob is used for this. As there is no point in firing with less than the four central weapons, the entire selector switch can be eliminated. A centrally mounted cluster of two MG 151 and two MG 17 machine-guns offers major advantages, and we are able to report that the MG 151 control system functions faultlessly.

On 4:
The following considerations concern the production ratio of the Fw 190 and the Bf 109, which has already been decided:
The engine is at present so unreliable that Colonel Galland considers the aircraft to be only of limited usefulness; flying the machine over the sea to England is not possible at present . . . the BMW 801C and D engines will take at least six months to be rendered reliable enough for service at the Front.
It is not safe to assume that an air-cooled power plant in the 2,000 hp range which is reliable enough for operational use will be developed in the long term. It is likely that further developments in enemy aircraft will force us to return to powerful liquid-cooled engines, in spite of the great advantages of air-cooled units.

It is intended to equip the Fw 190 with the DB 603, the liquid-cooled engine nearest in size to the BMW 801D . . . the DB 603 (is) a completely new unit, which will also have its teething troubles. We cannot expect this engine to be ready for the Front in less than a year (late 1942), but by then the 801D will be in a fit state for use at the Front.

The technical problems associated with the Fw 190 are thus bound to continue for a fairly long period, and in the meantime the only fighter aircraft which is actually fit for service use will continue to be the Bf 109F-4 or C (but the engine requires further development!).

There is uncertainty about the machine's usefulness over the Channel, and the same doubts apply to other sea areas and Russia. The availability of pilots is not so good that losses as a result of technical faults are acceptable.

The intended production ratio of approximately 50 per cent Fw 190 and 50 per cent Bf 109 indicates that other formations will soon be re-equipped. If this takes place, however, it will no longer be possible to ensure that these

Messerschmitt Bf 109F.

Messerschmitt Bf 109E. Engine cowling removed.

formations fly over our own territory only. For this reason it is essential that these aircraft must not be delivered until either the technical defects in the engine have been eliminated, or so many engines are in store, or available for subsequent supply, that it is possible to change engines regularly at short intervals, which is hardly to be expected.

Developments have also shown clearly that the Bf 109 will always remain faster and a better climber than the Fw 190. Climb capability is something we badly need. At the moment its climb performance may seem adequate in the particular conditions which obtain in combat over the Channel . . . its inferiority with the BMW 801C compared with the Bf 109F-4 is a full 50 per cent in the time to climb to 10,000 m. With the 801D the inferiority will still amount to around 25 to 30 per cent. Bearing in mind these considerations, the production ratio of 50 per cent for the Fw 190 appears to be too high, even when the great vulnerability of the Bf 109 in the air is taken into account.

signed Gollob[25]

It should be pointed out here that Milch, in an address to the Industry Council and the leaders of the companies on 18 August, 1941, had given the monthly output as '. . . Me 109 remains temporarily at 200, this figure to be reduced when Fw 190 production is raised from 170 to 485 . . .'

This report is reproduced here at such length because it shows clearly the full extent of the problems involved in German single-seat fighter procurement. Production had to be expanded, for the war on three fronts — in the West, Africa and Russia — called for more aircraft than had been planned, and the personnel and material losses had been high. The Bf 109 had certain deficiencies which were now becoming more obvious as more and more younger, less experienced pilots came into service. Should production of the Me 109, and inevitably the liquid-cooled DB engines, be expanded, or should production of the Fw 190 be increased to exploit the capacity for BMW 801 production? On the one hand the outcome was a rather vulnerable aircraft, greatly superior in rate of climb and altitude performance (Willy Messerschmitt's preoccupation with weight-saving had borne fruit here). On the other the outcome was a heavier, more robust machine designed for slightly heavier armament. Even if the problems with the 801 engine had not existed, the choice would still have been difficult.

In fact the engine situation for the Fw 190 was not quite as hopeless as had been feared in the report on the comparative tests. When the teething troubles of the BMW 801 mentioned by Gollob had been overcome, the Fw 190 turned out to be a very good fighter and fighter-bomber. In one respect Gollob was proved right: a more powerful air-cooled engine was never developed. In the quest for greater power it proved necessary to return (later) to liquid-cooled engines.

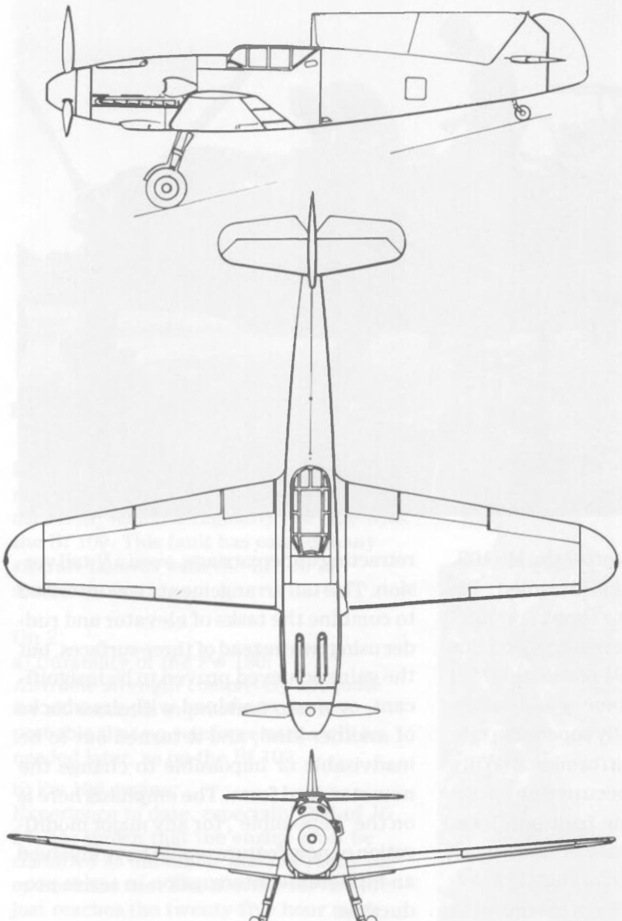
In the form in which the Bf 109 and Fw 190 had taken part in the comparative flight testing at the end of 1941, the two machines became standard equipment for fighter and fighter-bomber formations virtually until the end of the war. It is true that many fittings, items of equipment and auxiliary apparatus were altered, with the result that a great number of production series were completed, but in their external form, the shape which is subjected to the airflow, more or less nothing changed. A wide range of modifications for the 109 were built and tested, including a nosewheel variant, one with inward-retracting undercarriage, even a V-tail version. This tail arrangements was intended to combine the tasks of elevator and rudder using two instead of three surfaces, but the gains achieved proved to be insignificant, or were combined with drawbacks of another kind, and it turned out to be inadvisable or impossible to change the now standard form. The emphasis here is on the 'impossible', for any major modification or new feature would have involved an intolerable interruption in series production.

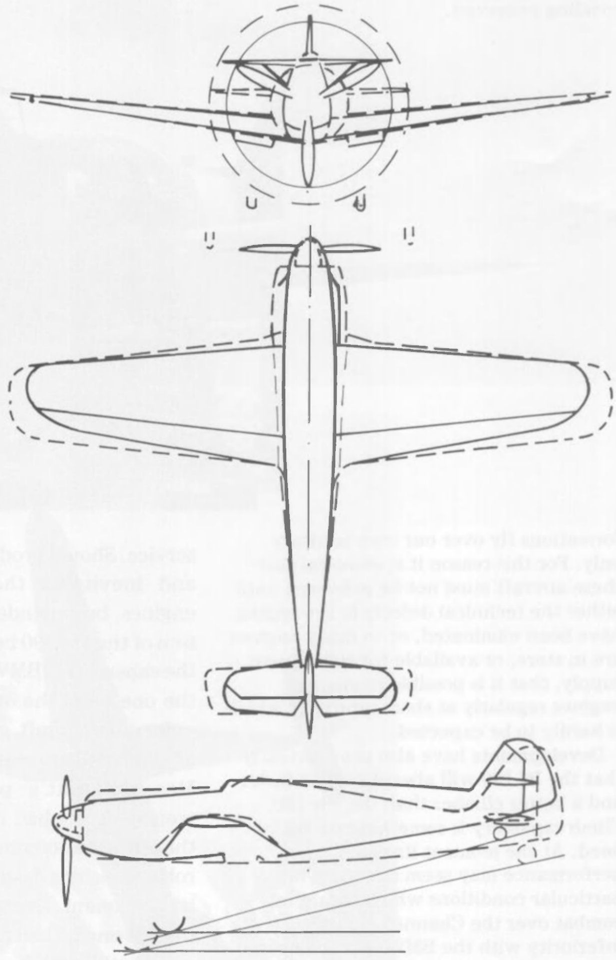
If we lay the three-view drawing of the Bf 109F (G, K) over that of the Fw 190A (B), as we did at the beginning of this book with the 1915 Fokker E 1 and the 1936 Bf 109B, there appear to be no significant differences. We will therefore consider the two aircraft side by side, to discover the (minor) differences and their effects.

Fw 190 and Bf 109 — Technical Comparison

The table overleaf compares a number of specific features of the Fw 190 and Bf 109F-4, alongside the correponding values for the Bf 109E, the 109 of the Battle of Britain in autumn 1940.

Because of the high power-to-weight ratio and the higher maximum power altitude the Bf 109F was inevitably better than its competitor at increasing altitude, as was confirmed in the Rechlin test reports. The 109 also had a tighter turning radius at increasing altitude as a result of its lower wing loading and power loading. It is interesting to compare the 109E and 109F-4, as this shows how an improvement in power loading is accompanied by an increase in wing loading (unless the wing area is altered).





Above: Messerschmitt Bf 109F

Above right: Bf 109F and Fw 190A to the same scale

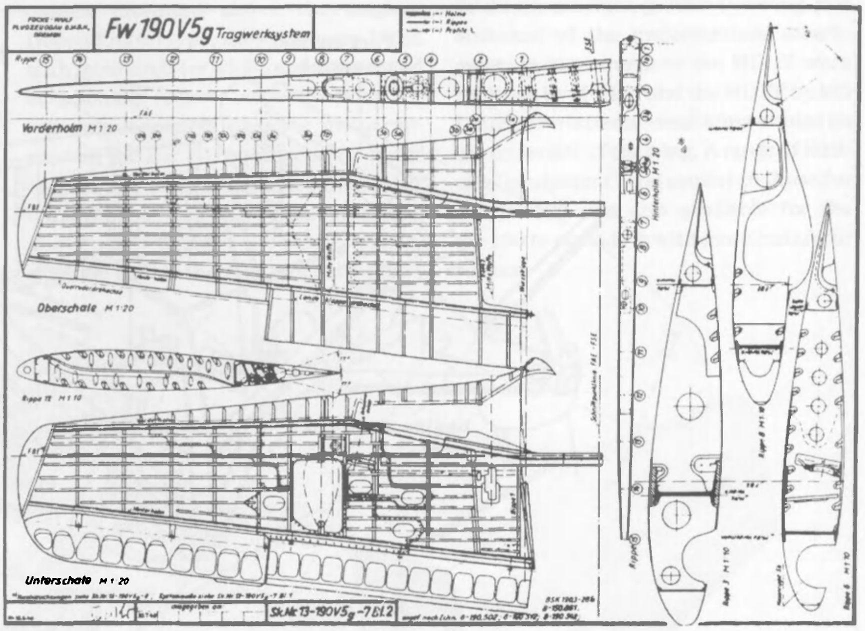
Comparison between Fw 190A, Bf 109F and Bf 109E

Type	Fw 190A	Bf 109F-4	Bf 109E-3
Engine	BMW 801	DB 601E	DB 601A
Combat power kW/hp	1,000/1,360	865/1,180	750/1,030
at altitude m	6,000	6,000	5,200
Wingspan m	10.5	9.92	9.87
Length m	8.95	8.94	8.76
Wing area sq m	18.3	16.1	16.35
Airframe weight kg	3,180	2,390	2,126
All-up weight kg	3,855	2,890	2,665
Wing loading kg/sq m	210	180	163
Armament	2 MG 17	2 MG 17	2 MG 17
	2 MG 151	1 MG 151/20	1 MG 151/20
	2 MG FF		
Speed at combat power	527/0*	495/0	471/0
km/h at altitude m	610/5,800*	595/5,200	560/4,400
		594/6,000	540/6,000

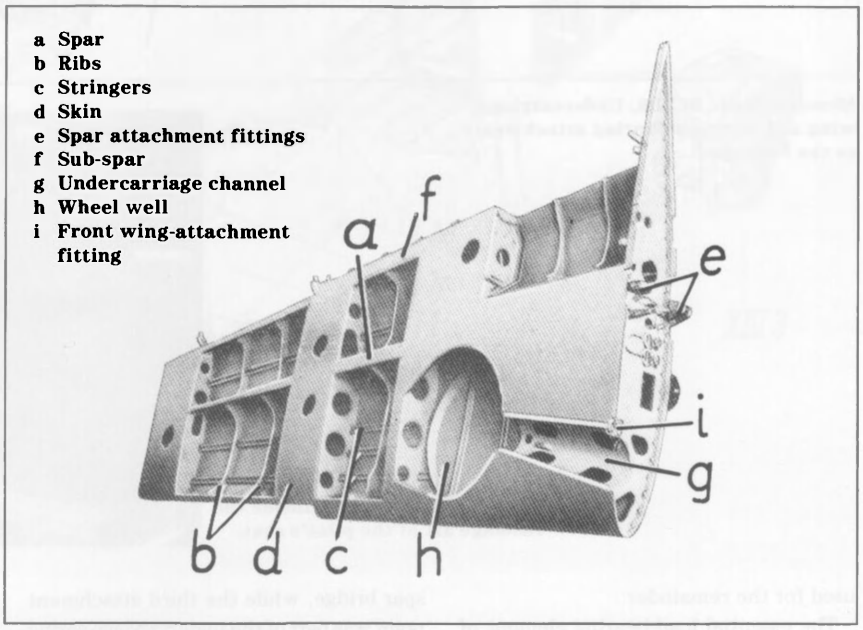
* Company figures

From this comparison it is clear that the Fw 190 should have been the inferior aircraft, but it had two clear advantages: superior roll manoeuvrability and acceleration in a dive, which gave the pilot the chance to get into a firing position from an unfavourable situation, or to escape from the enemy if he was surprised. The Fw 190 gained a reputation for quite outstanding roll response. In contrast to the Bf 109, whose excessive aileron control forces at high speed were a constant source of complaint, the Fw 190's aileron force compensation was excellent. Both aircraft were fitted with ailerons whose leading edge was forward of the pivot axis. On the Bf 109 this part had a circular arc-shaped profile which was designed to keep the gap between aileron and wing as narrow as possible. The Fw 190 featured Frise ailerons, in which the aileron leading edge is extended to form a sharp edge. On the upgoing aileron this part projects below the wing, and air pressure reduces the load produced by the top surface of the aileron. The Fw 190's wing also possessed great torsional rigidity. When an aileron is

Focke-Wulf Fw 190. Wing structure.

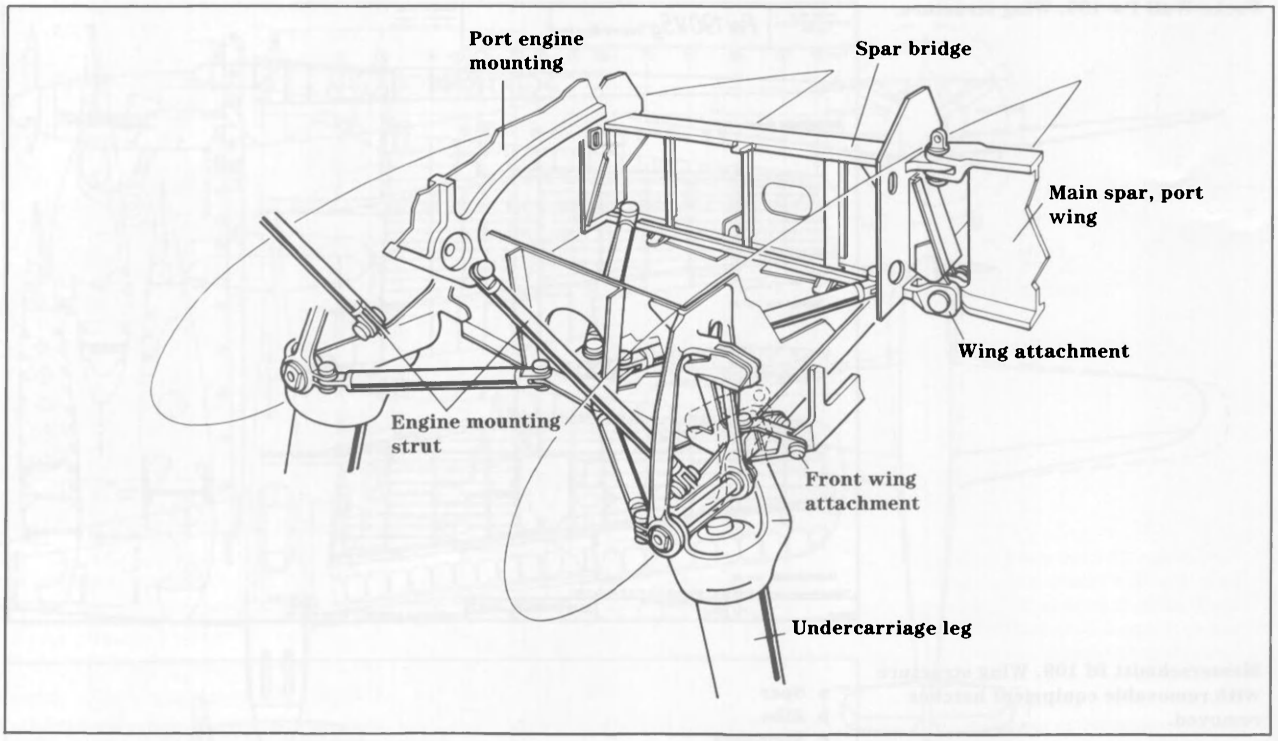


Messerschmitt Bf 109. Wing structure with removable equipment hatches removed.

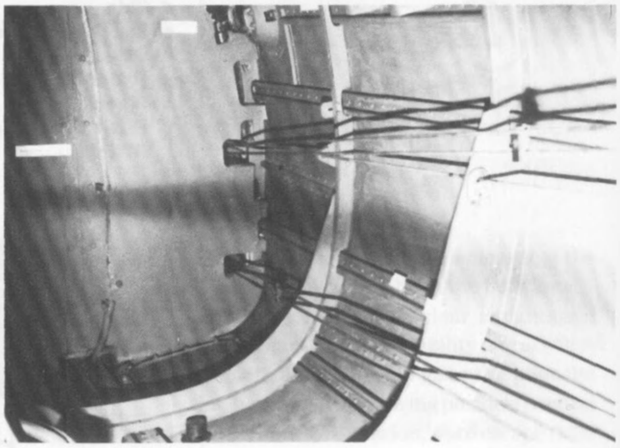


deflected, the wing tends to twist in the opposite direction. This tendency increases as speed rises, until the aileron reversal speed is reached, *i.e.* force is required to move the aileron, but its deflection has no effect. With stressed-skin construction the wing skin has to be strong enough to absorb the bending forces, and if this is the case the skin has an abundance of strength for the torsional loads, *i.e.* torsional stiffness is high. In contrast, the traditional Messerschmitt single-spar wing, as used on the 109, had plenty of strength in the bending plan, but relatively low strength in torsion. Torsional stiffness was further reduced by the large cut-outs and apertures in the wing skin for radiator, undercarriage and weapons installation.

The wingtip adopted for the 109F (and also for the Bf 110), was different from the previous version, but the change was not intentional. As an experiment a 109E wing was built with the span reduced by one metre. This machine, the Bf 109 V24, was tested and the wing found to be too small. Rounded wingtips were added to bring the wingspan up to around 10 m again, but the ailerons were not extended, and now ended at 87 per cent of the semi-span. The overall result was a further decline in aileron effectiveness. The illustrations show the fundamental differences in the wings of the two aircraft. The top and bottom shells of the Fw 190 wing were constructed separately, and connected by two widely spaced webs. The forces acting on the wing skins were transferred to a massive spar at the wing root, located at about one third of the chord. The spar was continuous from one side to the other, and formed the main attachment between wing and fuselage. The aft web extended as far as the fuselage side, where it was connected to a reinforced bulkhead. Full ribs were employed at the highly loaded points, where the undercarriage and weapon mountings were attached, with half-ribs



Messerschmitt Bf 109. Undercarriage, wing and engine mounting attachments to the fuselage.



Messerschmitt Bf 109. Inside the fuselage aft of the pilot's seat.

used for the remainder.

The essential load-bearing element of the Bf 109 wing was a stout spar, at 45 per cent of the wing chord. It was located so far aft in order to accommodate the wheels. The upper wing skin was uninterrupted, and was stiffened with widely spaced ribs and longitudinal profile strips. A large proportion of the undersurface was covered with removable hatches, located between strong full ribs. The problem of transferring the forces around the various apertures called for some imaginative engineering, and was a daring piece of work. A powerful spar bridge was an integral part of the fuselage, and the two wing panels were attached to the fuselage sides at three points: the top and bottom spar flanges were connected to the spar bridge, while the third attachment point was part of the undercarriage spring strut fitting. The same fitting also held one end of the engine support strut; thus three substantial loads were transferred into the fuselage via a single component, albeit fairly complex and rather difficult to make.

The differences in fuselage design were minor, although the methods of manufacture were quite different. In both cases the front section supporting the engine was attached to a central upper section which formed the pilot's compartment, to which in turn was attached the enclosed rear fuselage, which was stiffened with formers and stringers. In the 109 flanges formed in the skin itself acted as the rear fuselage formers, a technique which resulted in relatively short skin sections. The 109 featured separate formers which allowed longer skin panels to be used.

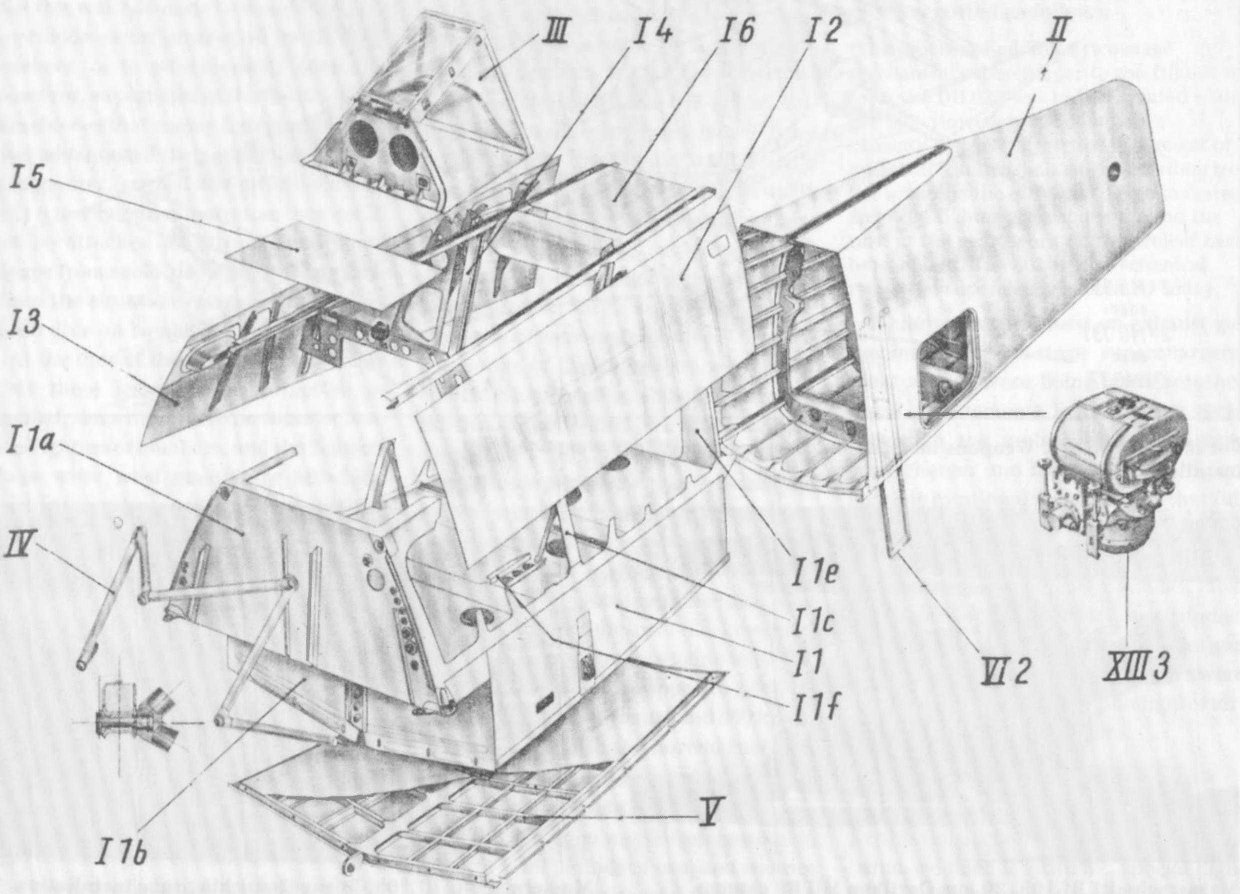
On both aircraft the tail surfaces and tailwheel were mounted in a separate tail section, which made the installation of the control systems and retracting mechanisms easier.

Armament. From the outset, *i.e.* since 1934, the Bf 109 had been designed to accommodate one cannon firing through the propeller hub and two machine-guns, synchronised with the propeller, mounted above the engine and firing through the propeller disc. The type retained this basic arrangement throughout its life with only minor variations and modifications.

The 109E was built in two versions: one

with two MG 17 machine-guns mounted above the engine plus two 20 mm MG FF machine-guns in the wings with 60 rounds each, and the other with a central 20mm MG FF machine-gun with 200 rounds, plus two MG 17 machine-guns above the engine. The succeeding types F, G and K were all equipped with a central motor cannon of 20 mm calibre (30 mm on the 109K), plus machine-guns of 7.9 or 13 mm calibre mounted above the engine. Depending on type, they were also fitted with mountings for additional cannon and occasionally rockets below the wing.

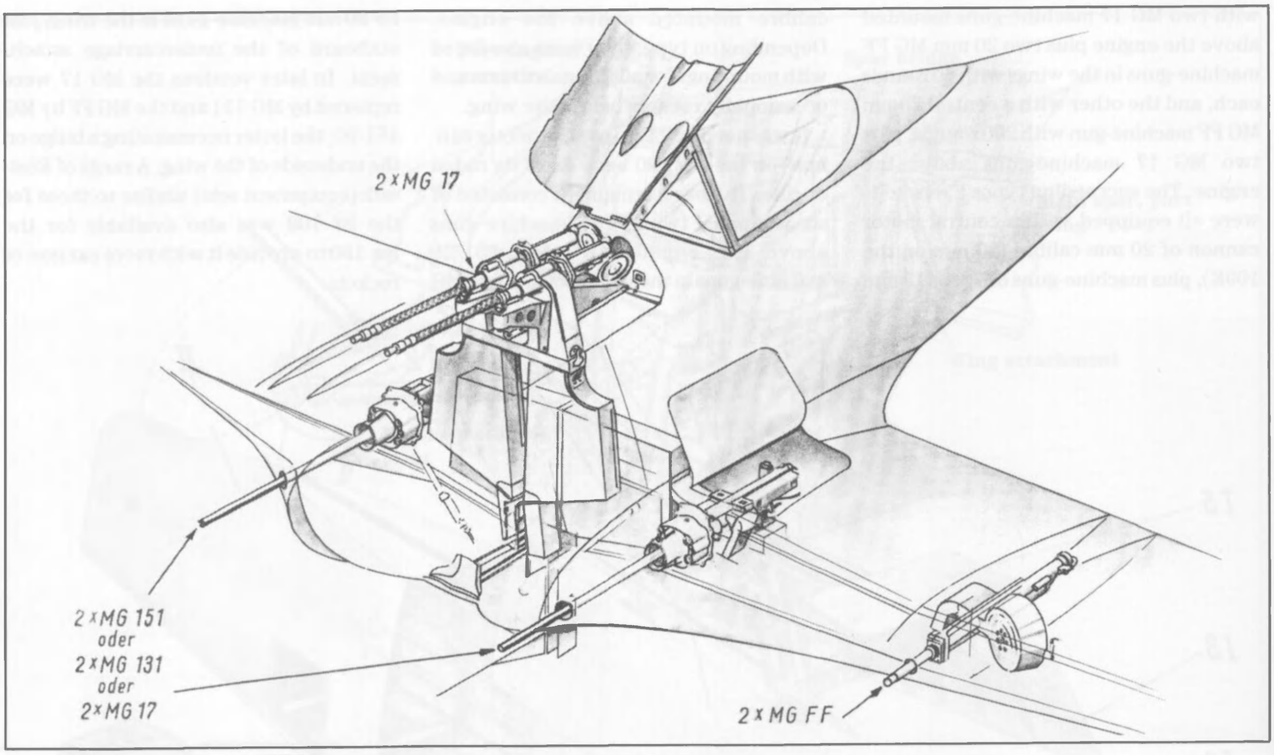
It was not possible to use the 'motor cannon' on the Fw 190 because of its radial engine. The basic armament consisted of six weapons, two MG 17 machine-guns above the engine, two MG 151/20 machine-guns in the wing root and two MG FF 20 mm machine-guns in the wing, just outboard of the undercarriage attachment. In later versions the MG 17 were replaced by MG 131 and the MG FF by MG 151/20, the latter necessitating a bulge on the underside of the wing. A range of Rüstsatz (equipment sets) similar to those for the Bf 109 was also available for the Fw 190 to provide it with more cannon or rockets.



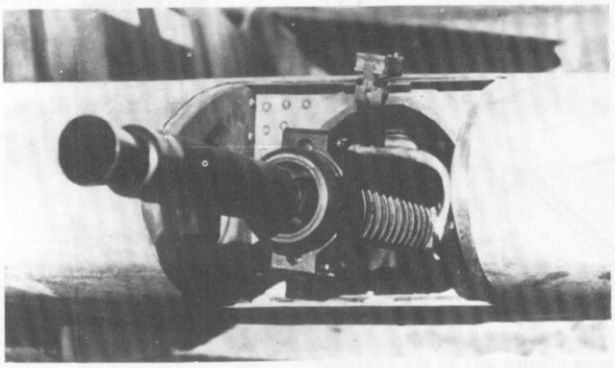
Focke-Wulf Fw 190. Fuselage construction, using separately built segments.

Specification of the most important Bf 109 series

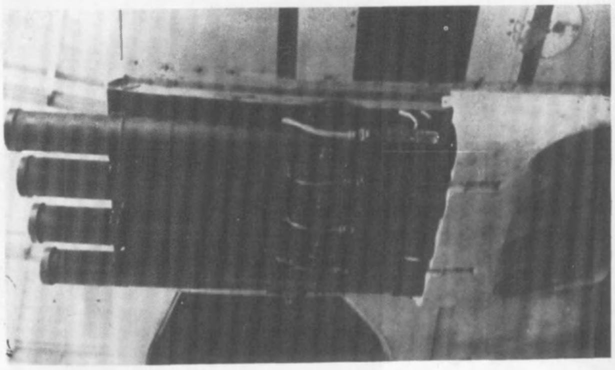
		B-1	D-1	E-3	F-4	G-6	K-4
Engine		Jumo 210D	Jumo 210D	DB 601A	DB 601E	DB 605A	DB 605D
Take-off power	kW (hp)	500 (680)	500 (680)	810 (1,100)	1,000 (1,360)	1,085 (1,475)	1,320 (1,800)
Wingspan	m	9.87	9.87	9.87	9.92	9.92	9.92
Length	m	8.70	8.70	8.76	8.94	8.97	9.02
Wing area	sq m	16.35	16.35	16.35	16.02	16.02	16.02
Airframe weight	kg	1,580		2,125	2,390	2,680	2,755
All-up weight	kg	2,050	2,170	2,665	2,900	3,200	3,400
Wing loading	kg/sq m	125	133	163	177	195	208
Armament		3 × MG 17	4 × MG 17	2 × MG 17 2 × MG FF	2 × MG 17 1 × MG 151/20	2 × MG 131 1 × MG 151/20	2 × MG 131 1 × MK 108



Focke-Wulf Fw 190. Weapons installation. In general only four weapons were installed.



Messerschmitt Bf 109. 20 mm Oerlikon MG FF cannon installation in the wing.



Messerschmitt Bf 109. Rocket launching tube installation beneath the wing.

Messerschmitt Bf 109. Hole through mainspar for cannon installation, and interrupted aileron linkage.

High-altitude Fighter Development

At the time of the Battle of Britain the service ceiling of fighter aircraft, *i.e.* the altitude at which they were still capable of flying a turn with perhaps fifteen degrees of bank without losing height, was no more than 10,000 m, and that of the best bombers 2,000 m less. It was thought that this was adequate to enable fighters to provide escort protection for friendly bombers, or to attack enemy bombers. However, experience in the Battle of Britain showed that enemy fighters had a distinct advantage if their maximum altitude was greater, even if the difference was only a few hundred metres,as they could not be attacked at altitude, and could escape from a solo 'dog-fight'. At any time when the situation was favourable they could dive on bombers and fighters.

At the time of the Russian compaign in 1941 these lessons were forgotten or ignored, since there were no superior Russian fighters or bombers, and the fighters there were used mainly for attacking ground targets in any case. When, early in 1941, Kurt Tank spoke to Udet and Jeschonnek (Chief of General Staff) about the desirability of a high-altitude engine for the Fw 190, he received the answer: 'What for? We don't fight aerial combat at such altitudes.' But the ideas of the Luftwaffe leaders changed suddenly after a minor advance in Rolls-Royce engines gave the advantage in altitude to the British Spitfire single-seat fighter and especially to the twin-engined (unarmed) Mosquito light bomber and reconnaissance machine. The process of producing a high-altitude engine was accelerated when exhaust gas turbo-chargers were obtained from a B-17 shot down in September 1941 over Norway. The Reichsmarschall announced that 'altitude is what we need', and waited for industry to produce a high-altitude fighter at the drop of a hat. He and the General Staff had still not realised that it took years to develop a production aircraft or a substantially modified engine designed for a new task. As far as engines were concerned, there were three possible alternatives:

1. Increasing supercharger power using a two-stage supercharger, either driven mechanically or via an exhaust gas turbine; the latter course would inevitably take longer to produce, because the exhaust gas turbine would have to be developed in addition to the supercharger itself.

2. Injection of a mixture of water and methanol, which allowed an increase in power of around fifteen per cent from ground level up to maximum altitude. However, this method could only produce a really significant gain in power if a multi-stage supercharger was used.

3. Additional injection of a buffered oxygen carrier, di-nitrogen monoxide, also known as nitrous oxide or laughing gas, chemical formula N_2O. This substance was given the code name GM-1, and consisted of 36.4 per cent oxygen plus 63.6 per cent nitrogen. In its liquid state it had a specific mass of 1.2 kg/litre. Nitrous oxide liberates a relatively large amount of heat when it decomposes, and the heat is released inside the engine. It was carried in the aircraft in its liquid form at -88 degrees C in insulated containers. The disadvantage of the technique was that it could only be used at altitudes at which the sum of the original power and the gain due to GM-1 did not exceed the full pressure altitude power, *i.e.* there was no gain in the aircraft's climb performance at lower altitudes, and in fact the additional weight reduced performance. The consumption of the substance was also relatively high. The quantity of GM-1 required to raise the output of an engine to its full 1,340 hp when it had dropped to 1,000 hp at 9,000 m altitude was around 360 kg per hour in addition to the normal fuel consumption of approximately 300 kg/h, not to mention the weight of the extra apparatus. The technique was therefore suitable only for brief periods of use, and was not really applicable to normal fighters. The apparatus required for the two supplementary injection processes, MW 50 and GM-1, were extremely simple, and had soon undergone testing and were ready for use. The Bf 109G and K, in which the only major change was the DB 605 engine in place of the DB 601, were built with both GM-1 and MW 50 systems. Both techniques were also applied to the BMW 801 engines used in the Fw 190.

Other aspects of the work aimed at increasing power output at altitude made slow progress. Despite the fact that aircraft and engine companies had long since calculated that, for high-speed aircraft, the energy in the exhaust gases would be better exploited in jets than in exhaust gas turbo-chargers, much effort was spent on the latter. If we take into account the additional weight of the machinery, the larger, heavier propeller, the cooler for the charging air and its drag, this is no surprise.

There was a long delay before work could start on a two-stage supercharger for the BMW 801. A study group was set up for the planning of engine development, and its first meeting was held on 4 November, 1942 — one year after Gollob had written his comparative report on the two fighters at Rechlin. On the BMW 801 the group reported as follows:

'The process of adding a two-stage mechanical supercharger to the DB 605 to form the DB 628 was to be repeated with the 801. However, the company's capacity was overstretched as a result of initial difficulties, and since according to the schedule the 801 was to be eliminated from the fighter programme around the turn of the year, work on the project has been halted. The 801 with mechanical two-stage supercharger could fly today.'

While work continued on exhaust gas turbines and two-stage superchargers, great strides were being made in other areas. Refinements in fluid flow techniques in the multi-speed single-stage supercharger and improvements in permissible rotational speeds meant that full pressure altitudes of 6,500 to 7,000 m became possible. This was the best solution for combating bomber attacks, most of which were made from these altitudes, and in consequence neither exhaust gas turbines nor two-stage superchargers were used operationally in German fighter aircraft in significant numbers.

Fw 190D; Ta 152H

At the time when Göring declared that 'what we need is altitude', special high-altitude fighter aircraft had been planned for the two-stage supercharged engines DB 628, DB 603L and Jumo 213E: the Bf 109H at Messerschmitt and the Ta 152H[26] at Focke-Wulf.

The Ta 152 was a revised version of the Fw 190D-9, which was to be equipped with the liquid-cooled DB 603 engine in place of the original air-cooled BMW 801. The Ta 152H was a variant of the 152 with an enlarged wing. Problems were experienced with the various high-altitude versions of the DB 603, and the Jumo 213 was selected to replace it. This had the same capacity as the Jumo 211, which had been the standard power plant of the Ju 88 bomber in the early years of the war. In its A-version with single-stage two-speed super-charger the 213 produced just over 30 per cent more power on take-off and

at the full pressure altitude of around 5,500 m. The machine was tested at the Rechlin test centre, and the (abbreviated) report dated 19 March, 1945(!) provides the following information on the performance of the Fw 190D:

'Fw 190D-9 with Jumo 213A
Rechlin test centre, test report 9003
19.3.1945
. . . Speed tests were conducted flying Works No. 006. For continuous testing various Works Numbers were flown at n = 3,000 rpm . . . speed at ground level between 520 and 530 km/h, at 6,500 m altitude (approximate full pressure altitude) between 625 and 635 km/h. At n = 3,250 rpm and altitude = 6,600 m speeds between 645 and 655 km/h can be obtained, and at ground level between 540 and 550 km/h. Climb speed at ground level at n = 3,250 rpm, w = 17.0 m/sec, at 10.2 km w = 2.0 m/sec. at take-off weight of 4,300 kg.

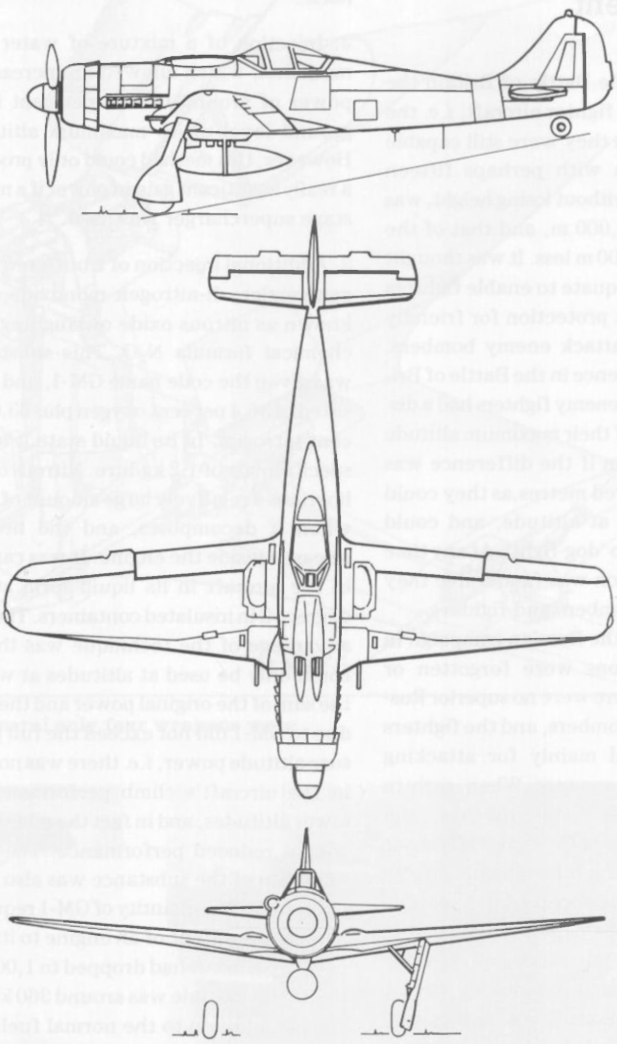
1. General information:

Aircraft type:	Fw 190D-9, Works No. 21006
Aerodynamic wing area:	F = 18.3 sq m
Wingspan:	b = 10.46 m
Engine:	Jumo 213A (B-4 fuel)
Permissible engine speed for 30 minutes:	n = 3,250 rpm
Permissible engine speed for continuous use:	n = 3,000 rpm
Suction system:	External inlet cowl without filter
Exhaust system:	Smooth recoil nozzles
Propeller:	Heine 3-blade core-hardened D = 3.5 m, t/D = 11.5%

State of aircraft:
Standard version with ETC 504 (without cover)
Engine: without gap cover
Surface filled, smoothed and sprayed as standard.

2. Weapons:	2 MG 131 with 425 rounds each in fuselage 2 MG 151 with 250 rounds each in wing (inboard)
Antennas:	for FuG 16 for FuG 25 for — apparatus and navigation frame
Take-off weight:	G = 4,350 kg
Fuel load:	640 1, of which 115 1 in supplementary tanks in fuselage. G = 4,640 kg if aircraft is flown with 300 1 drop tanks.

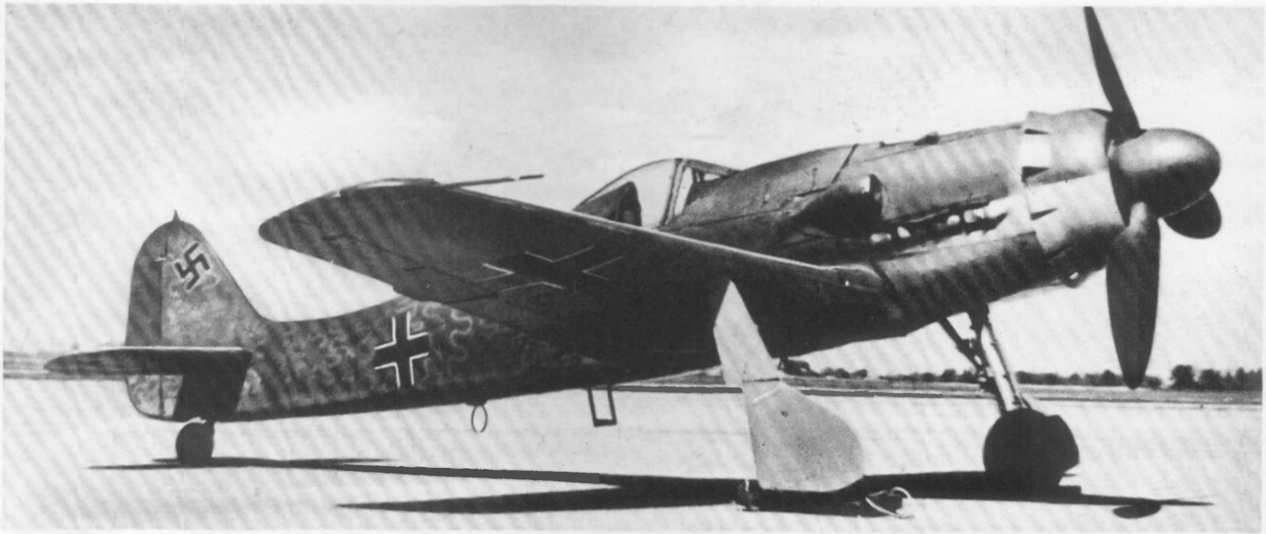
Focke-Wulf FW 190D-9, Ta 152



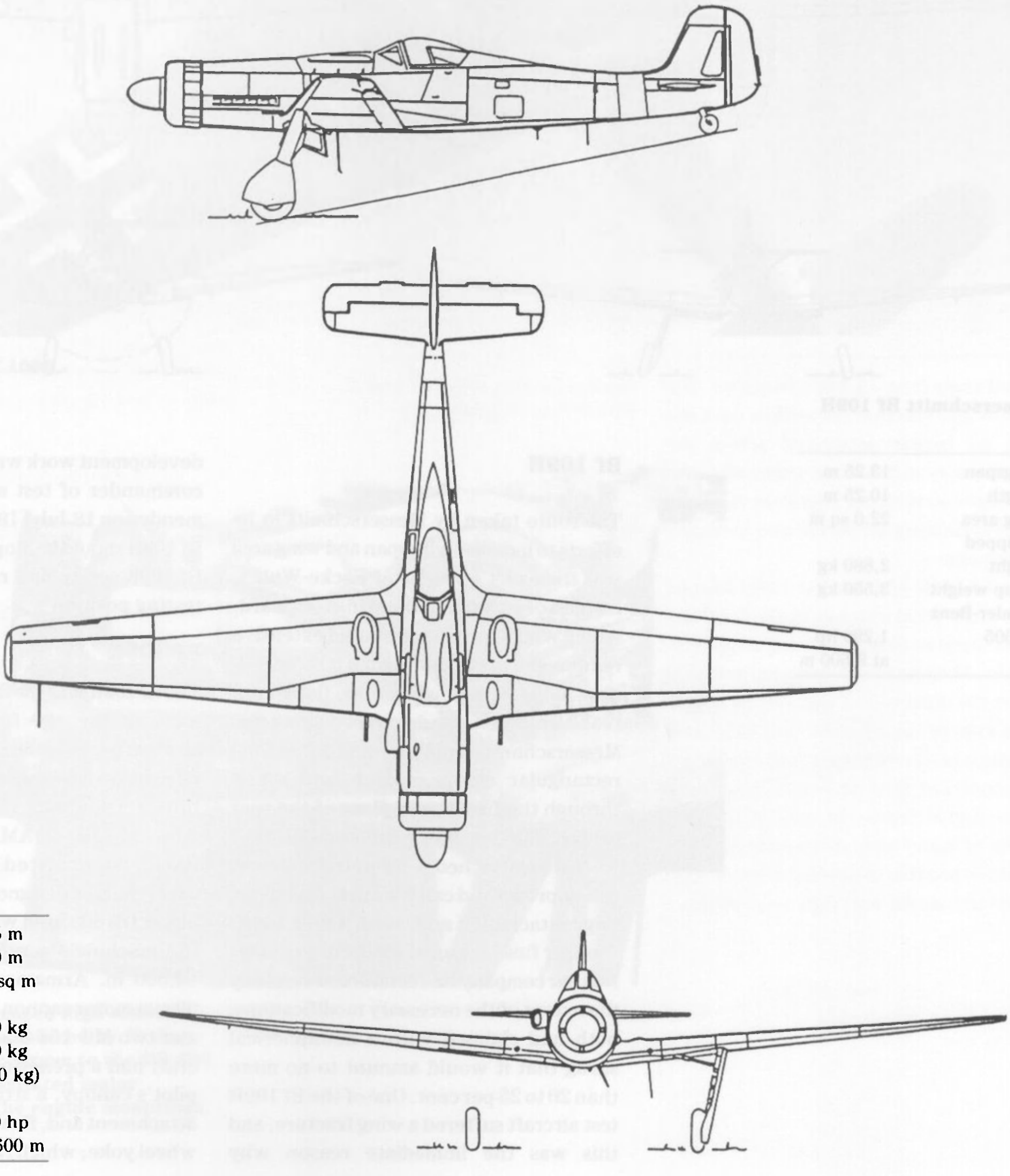
Results of measurements: speeds obtained earlier were around 15 km/h higher than speeds obtained with the same Works No. at 3,000 rpm (see report dated 15.11.44).'

The wings of the Ta 152 were increased slightly in span, to allow heavier armament to be accommodated in the wing root. The undercarriage moved outboard slightly as a result. The outcome was a wingspan of 10.7 m and a wing area of 19.5 sq m. The engine with its annular radiator projected far forward, and the tail had to be extended to maintain the correct centre of gravity and stability values. As a result the overall length grew by almost two metres to 10.7 m.

For the high-altitude version, the Ta 152H, the wing was increased again to 14.5 m span. The wing area had now risen to 23.3 sq m. Several different engines were available, but since other aircraft had also to be considered it was some time before a decision was made in favour of the Jumo 213E-1. This 35-litre engine produced a climb and combat output of 1,380 hp at its full pressure altitude of 9,600 m. The top speed of the high-altitude fighter was over 700 km/h, and with GM-1 altitudes of more than 14,000 m were achieved. But what was the point of climbing so high when the mass of bombers were operating six to eight thousand metres lower, and even the notorious Mosquito, a specially designed high-altitude reconnaissance aircraft, could fly no higher than twelve thousand metres? The Ta 152H never reached series production, and only a dozen aircraft were built.



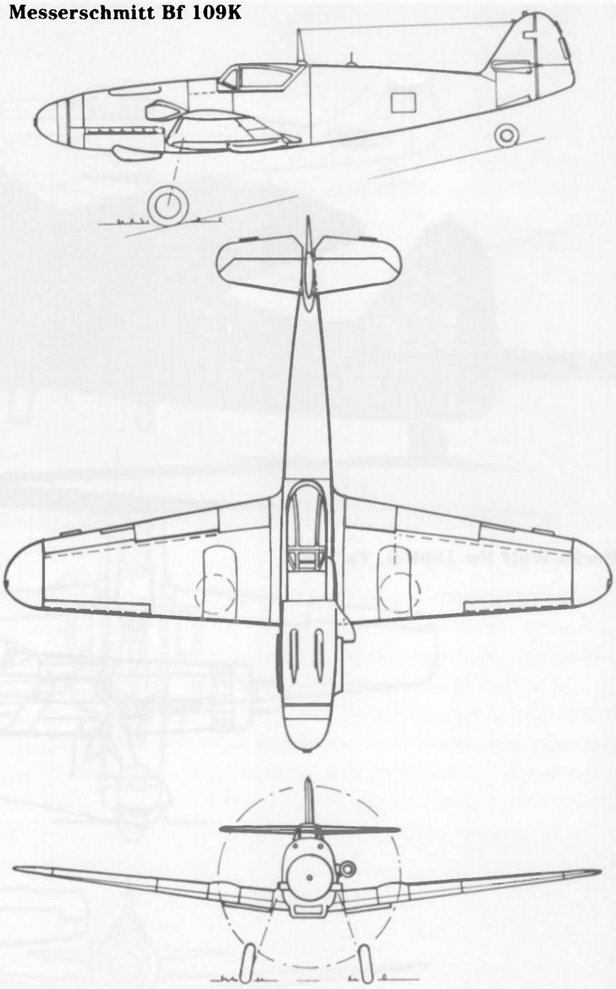
Focke-Wulf Fw 190B-9, Ta 152.

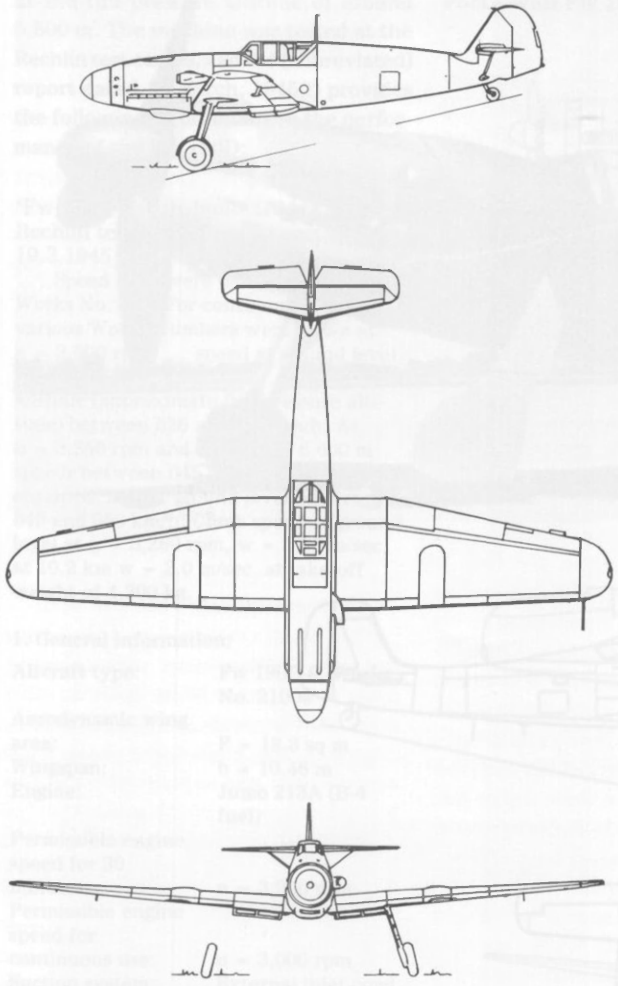


Focke-Wulf Ta 152H

Wingspan	14.45 m
Length	10.70 m
Wing area	23.3 sq m
Equipped weight	3,930 kg
All-up weight	4,750 kg (5,200 kg)
Junkers-Jumo 213	1,380 hp at 9,600 m

Messerschmitt Bf 109K





Messerschmitt Bf 109H

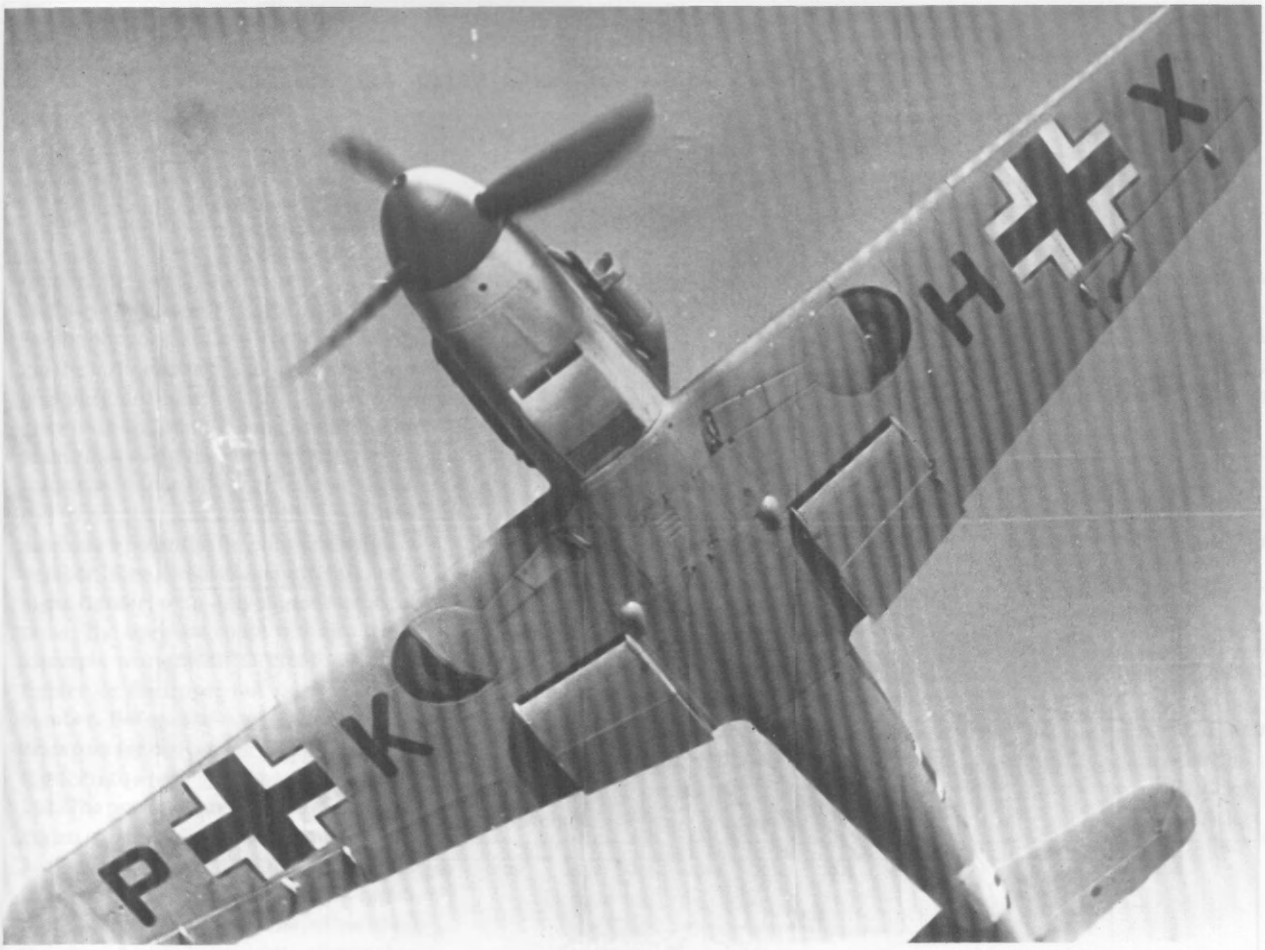
Wingspan	13.25 m
Length	10.25 m
Wing area	22.0 sq m
Equipped weight	2,880 kg
All-up weight	3,550 kg
Daimler-Benz DB 605	1,290 hp at 9,600 m

Bf 109H

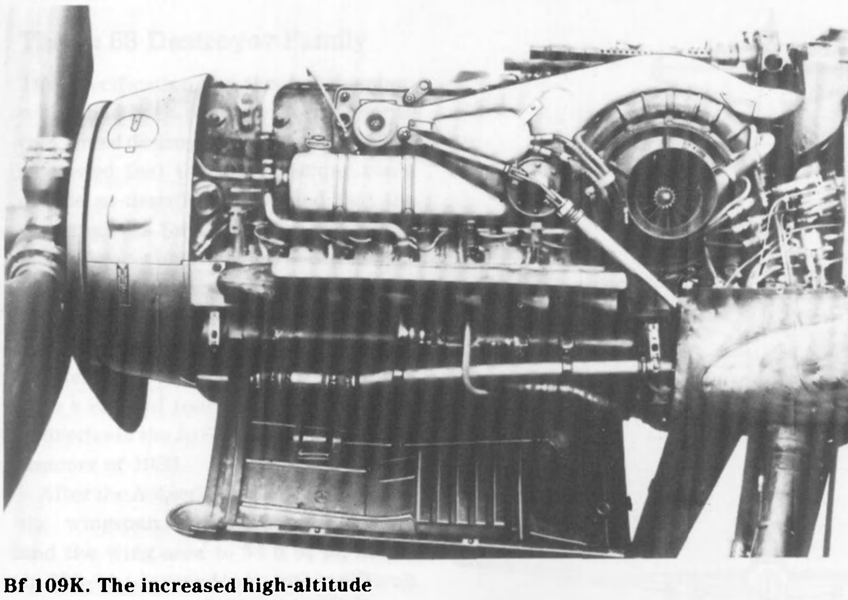
The route taken by Messerschmitt in its efforts to increase wingspan and wing area was the exact opposite of Focke-Wulf's. Instead of extending the wings outward, which would have necessitated extensive reinforcements to the original inboard section, along with new ailerons, flaps, control linkages and drive systems, Messerschmitt simply built a 3.3 m long rectangular centre section and set it through the fuselage in place of the spar bridge. The two wing panels of a Bf 109G were then attached to its ends. However, this approach did call for a new undercarriage attachment and, as on the Ta 152H, a longer fuselage and larger tail surfaces. Neither company had considered carefully the extent of the necessary modifications; both had claimed with a metaphorical shrug that it would amount to no more than 20 to 25 per cent. One of the Bf 109H test aircraft suffered a wing fracture, and this was the immediate reason why development work was halted. In fact, the commander of test stations had recommended on 18 July, 1944, that work on the Bf 109H should be stopped in favour of the Bf 109K series 'as a result of the present testing position'.

Bf 109K

The Bf 109K was the final stage of development of the 109 family, and its high-altitude performance was so good that the decision to cease work on the special altitude version was vindicated. Equipped with the DB 605AM engine, which had itself been fitted with the turbo-supercharger designed for the 25 per cent larger DB 603, and with MW 50 injection, the machine's service ceiling was over 12,500 m. Armament consisted of one 30 mm motor cannon, type MK 103 or 108, and two MG 151 machine-guns. The aircraft had a pressure cabin, an improved pilot's canopy, a stronger undercarriage attachment and, finally, an extended tail-wheel yoke, which reduced the aircraft's

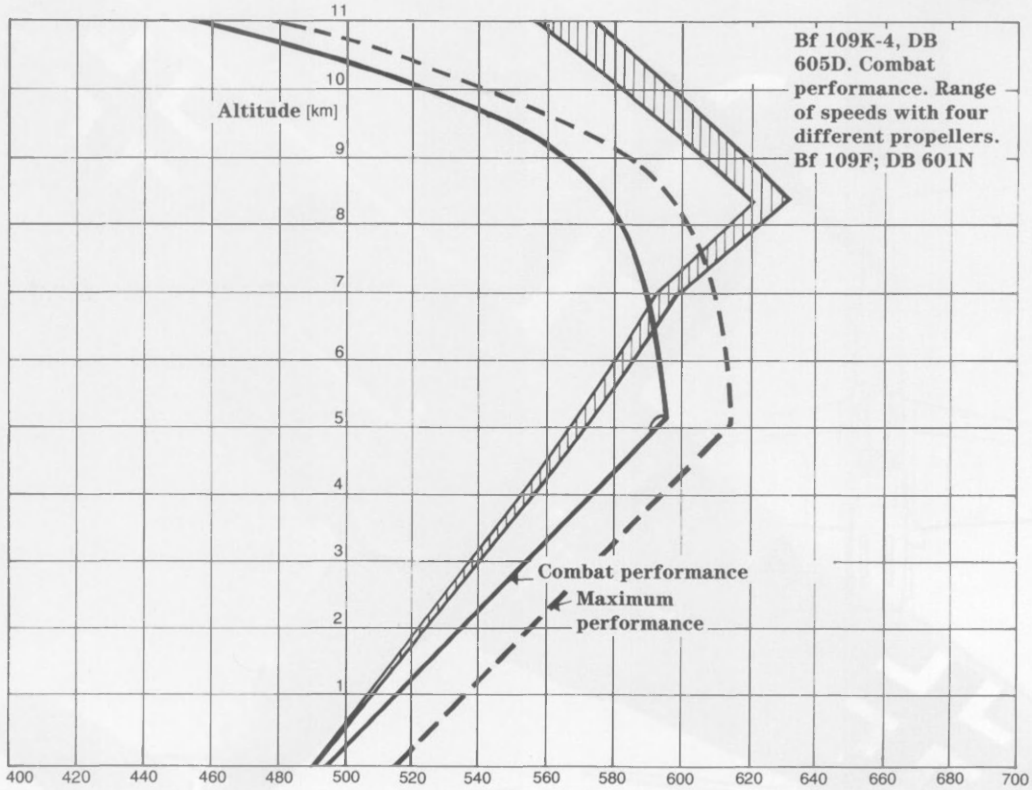


Messerschmitt Bf 109K.



Bf 109K. The increased high-altitude performance was achieved by fitting the DB 603 supercharger to the DB 605 engine. This necessitated major modifications to the engine mountings.

Maximum speeds of the Bf 109F and K



Messerschmitt Bf 109F and K. Performance chart.

ground angle from 14.5 to 13 degrees. The result of this was that the airflow over the wing no longer separated when the machine was at the three-point altitude. This, together with the improved view, led to fewer landing accidents and less taxiing damage.

The Bf 109K and the Fw 190D formed the worthy final chapter in the long history of German piston-engined single-seat fighters. They had been designed and built before the outbreak of war — long before in the case of the Bf 109 — but their performance had been raised again and again by a constant flow of improvements to engine and airframe. In spite of the best efforts of many aircraft designers, it did not prove possible to develop a better solution to the single-seat fighter problem.

Destroyer/Night-fighter Development in the Second Half of the War

During the war, the range of single-engined single-seat fighters covered just two basic types, but the situation regarding the twin-engined fighter or destroyer was very different; many designs were drawn up and built during the war. The main reasons behind this diversity were the rather vague, ill-specified role which the machine was to fulfil, and the machine's potential for conversion into a bomber, a reconnaissance aircraft, or a night-fighter, with only minor modifications. The opposite route was also tried: attempts were made to create a night-fighter or destroyer out of an existing bomber. Before the war plans had been drawn up for converting the Bf 110 heavy fighter into a high-speed bomber — the Bf 162. The possibility now arose of converting an existing high-speed bomber — the Ju 88 — into a destroyer. In the course of the war the terms destroyer and night-fighter were interchangeable, as both had the same heavy armament, all-weather and night-flying capability, fairly long flight duration and range as well as other features.

The Ju 88 Destroyer Family

The specification for the fast bomber, which had been planned as successor to the combat destroyer requirement of 1934, suggested that the new machine could double as destroyer, provided that the requirements for armament and equipment were set high enough. The first flight of the Ju 88 three-seat fast bomber took place on 21 December, 1936. A few modifications were required, principally dive capability and the conversion to accommodate a crew of four, and the first series deliveries of the Ju 88A-1 took place in the summer of 1939.

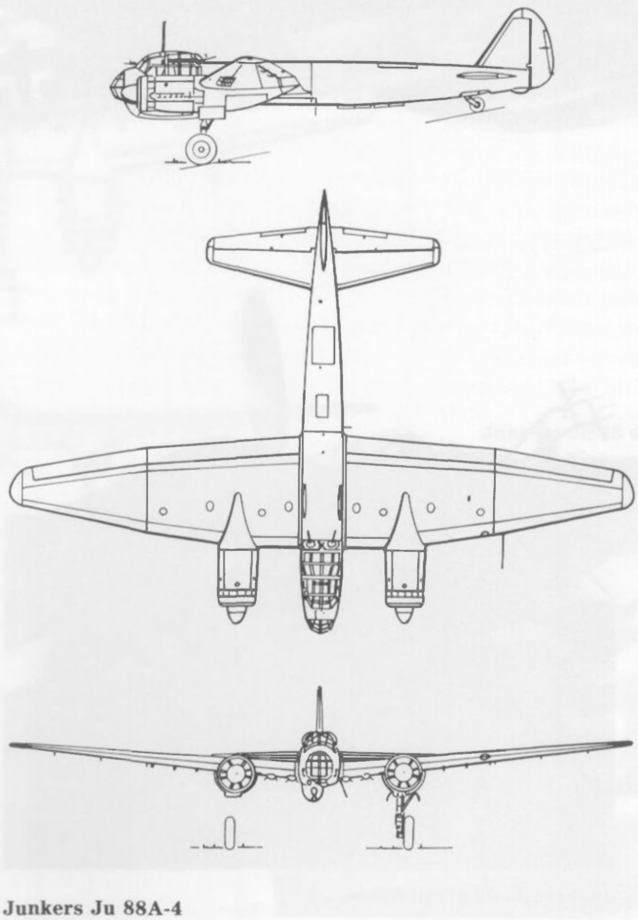
After the A-4 series had been produced, the wingspan was increased to 20 m and the wing area to 54.5 sq m, as the Ju 88A-1 had proved to be rather difficult to fly for the less experienced pilot. Secretary of State Milch visited a Ju 88 combat group, and sent a report dated 15 October, 1940, to the Reichsmarschall, which voiced the following complaints:

'Blind flying very difficult, especially at great altitude; single-engined flight uncertain; night landing very difficult; landing speed 200 to 220 km/h; final assessment by Group members: pilots trained in wartime have insufficient experience and are bound to be lost with their machines. The Group's sole fear is not the enemy, but the Ju 88.'

The airframe weight climbed to 9.9 tons and its all-up weight — depending on load — to 12 to 14 tons. In this revised form the Ju 88 was built for years. Its rear defensive armament usually comprised twin 7.9 mm MG 81 machine-guns, mounted top and bottom and firing to the rear. The series C was a further development with a modified cabin and glazing. It served as a three-seat destroyer and night-fighter with an attack armament of two 20 mm MG FF and two MG 17 machine-guns, and

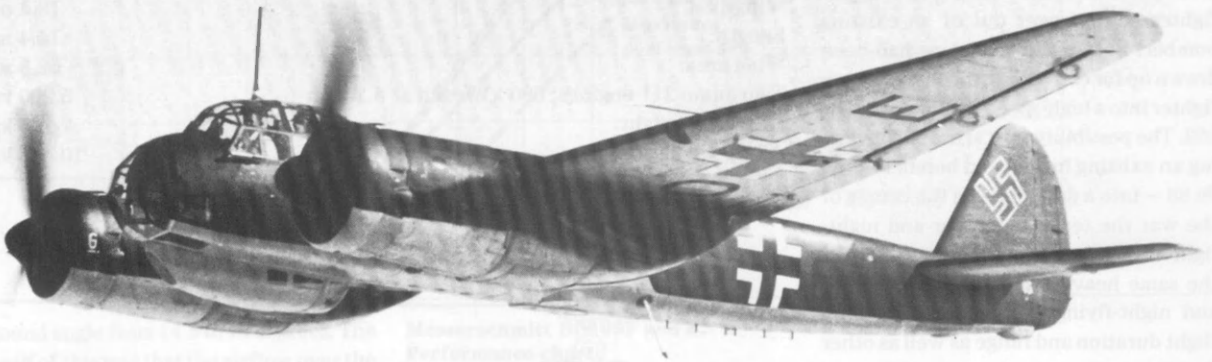
Characteristics of the Ju 88A-1 bomber

Wingspan:	18.4 m
Length:	14.4 m
Wing area:	52.5 sq m
Two Jumo 211 engines; 680 kW each at 5,200 m	5,200 m
Airframe weight:	7,700 kg
All-up weight:	10,400 kg



Junkers Ju 88A-4

Messerschmitt Bf 110 as a night-fighter.



Junkers Ju 88D-2.

Junkers Ju 88 night-fighter.

retained the defensive armament of the A-series.

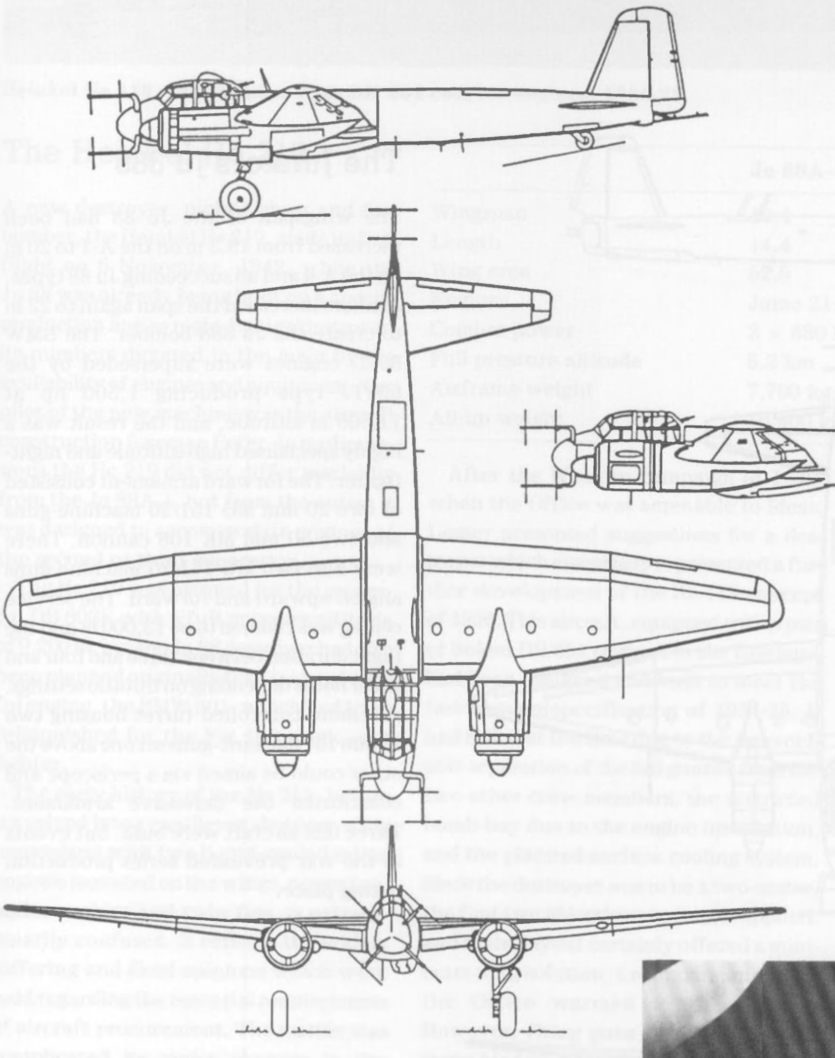
Although the Ju 88 had originally been planned as a bomber, almost a quarter of the total production of the aircraft up to the end of 1942 was built as a destroyer/night-fighter. The vast majority of the night-fighter squadrons flew these machines.

When the second, faster generation of British bombers called for a faster night-fighter, the response was the Ju 88G-series. Initially fitted with the BMW 801D, producing a continuous power of 1,500 hp at 5,300 m it was subsequently converted to take the Jumo 213E, which in its fully developed form offered a continuous power of 1,750 hp at 9,400 m.

Armament consisted of four 20 mm MG 151/20 machine-guns firing forward and two cannon of the same calibre angled to fire upward and forward. As the task of

Characteristics of the Ju 88 G-6 destroyer/night-fighter

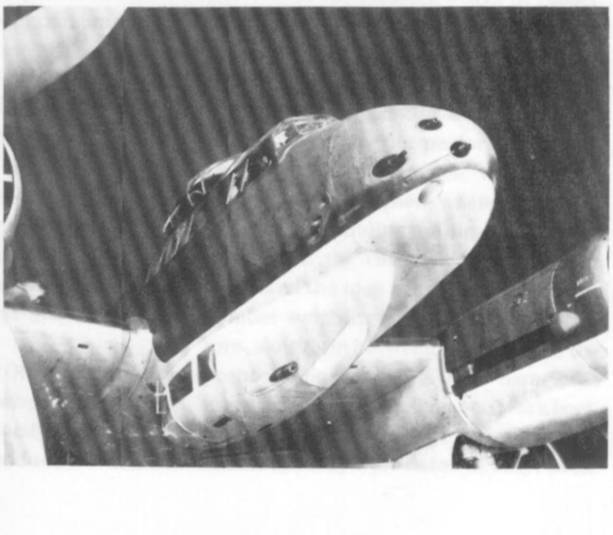
Wingspan:		20.0 m
Length:		14.9 m
Wing area:		54.55 sq m
Two Jumo 211, 780 kW (1,060 hp) each, at 5,200 m		5,200 m
Airframe weight:		9,100 kg
All-up weight:		12,400 kg
Armament: forward	3 × 20 mm MG FF	
forward	3 × 7.9 mm MG 17	
upward	2 × 20 mm MG 151/20	
rearward	1 × 13 mm MG 131	



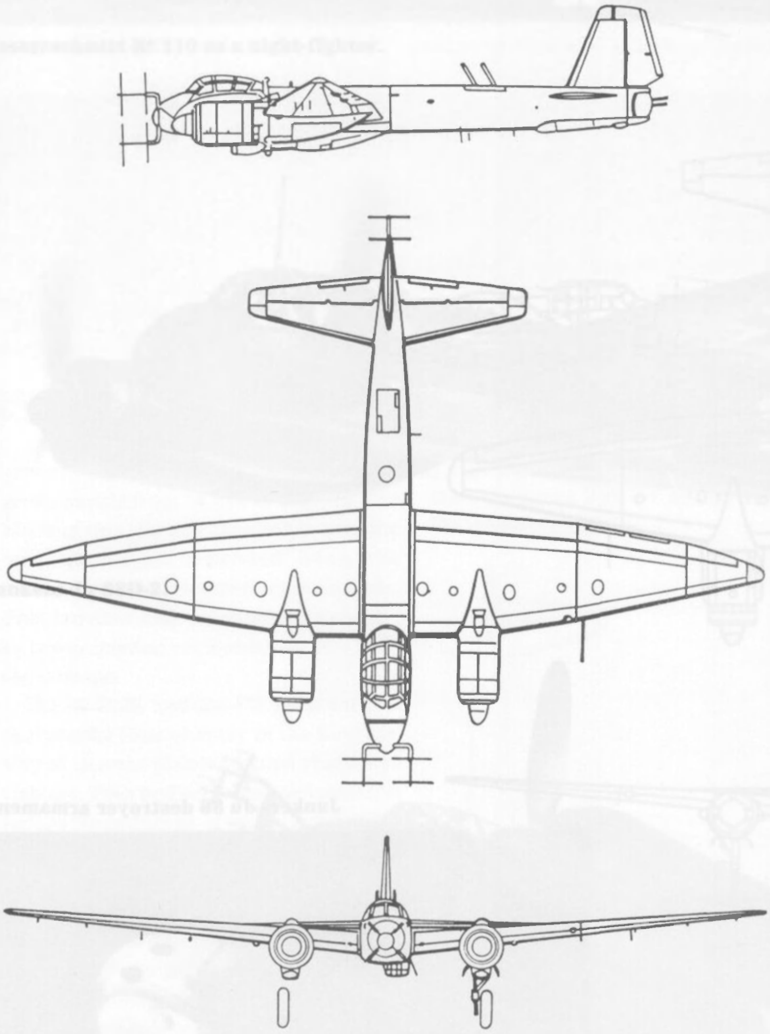
Junkers Ju 88 night-fighter with Jumo 213 G-6. BMW 801 installation shown inset.

locating the enemy, using a variety of electronic search apparatus, was becoming more and more difficult, a third man was added to the crew to relieve the load on the radio operator/navigator. The wingspan, wing area and length were identical to those of the Ju 88, but stability around the vertical and roll axes was reduced by the more powerful engines, and an enlarged tailplane and — in particular — fin became necessary. With a maximum speed of around 600 km/h at 9,000 m altitude the Ju 88G-7 was an outstanding night-fighter in performance terms. The aircraft would have been used in greater numbers had it not been for the delay in availability of the Jumo 213E.

Junkers Ju 88 destroyer armament.

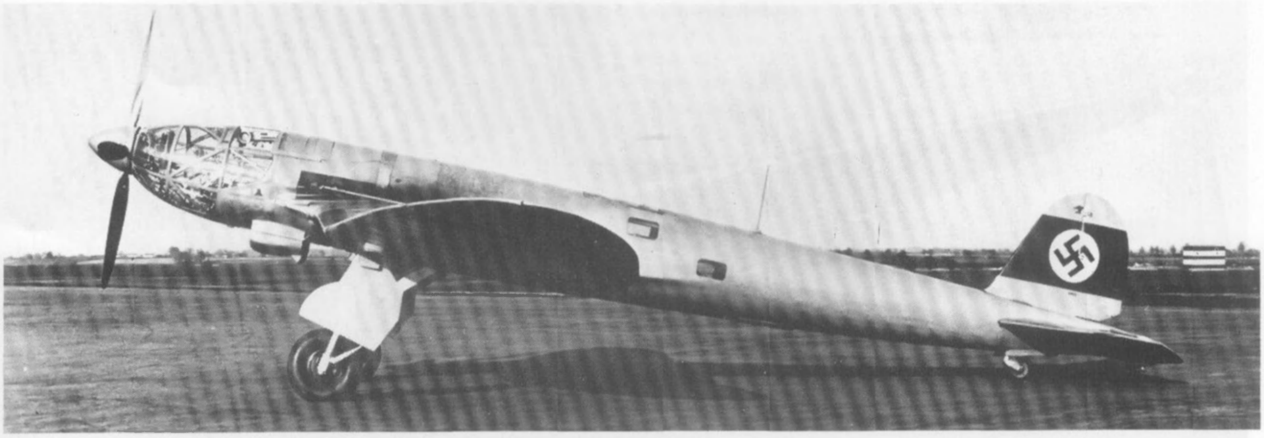


Junkers Ju 388 night-fighter.



The Junkers Ju 388

The wingspan of the Ju 88 had been increased from 18.3 m on the A-1 to 20 m on the A-4 and all succeeding Ju 88 types. Junkers increased the span again to 22 m to create the Ju 388 bomber. The BMW 801D engines were superseded by the 801TJ type producing 1,500 hp at 11,500 m altitude, and the result was a highly specialised high-altitude and night-fighter. The forward armament consisted of two 20 mm MG 151/20 machine-guns and two 30 mm MK 108 cannon. There were also two MG 151/20 machine-guns angled upward and forward. The service ceiling was claimed to be 13,000 m and the flight duration between three and four and a half hours depending on throttle settings. A remote-controlled turret housing two 13 mm 131 machine-guns set one above the other could be aimed via a periscope and constituted the defensive armament. Three test aircraft were built, but events in the war prevented series production taking place.



Heinkel He 119. Fast bomber with DB 601 coupled engines, 1936-38.

The Heinkel He 219

	Ju 88A-1	He 219 V1
Wingspan	18.4	18.5 m
Length	14.4	14.5–15.5 m
Wing area	52.5	44.5 sq m
Engines	Jumo 211	DB 603A
Combat power	2 × 680 kW	2 × 1,300 kW
Full pressure altitude	5.2 km	5.7 km
Airframe weight	7,700 kg	9,050 kg
All-up weight	10,400 kg	11,800 kg

A new destroyer, night-fighter and fast bomber, the Heinkel He 219, made its first flight on 6 November, 1942, while the Ju 88 was already being built on a special production line as night-fighter/destroyer, its numbers dictated in the main by the availability of engines and equipment. The pilot of the new machine was the aircraft construction foreman Peter. In its dimensions the He 219 did not differ markedly from the Ju 88A-1, but from the outset it was designed to accommodate engines of the second or third generation.

The He 219 was planned for the powerful DB 603E with a full pressure altitude of 9,200 m, but the Ju 88 destroyer had also been planned originally for a more powerful engine, the BMW 801, which had to be relinquished for the Fw 190 single-seat fighter.

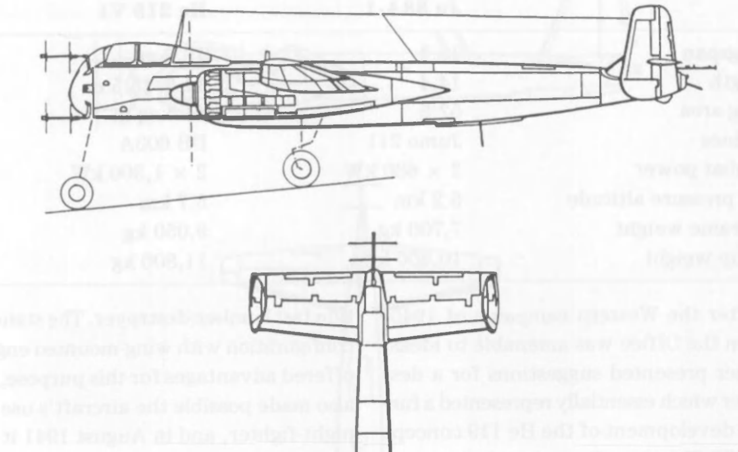
The early history of the He 219, before it evolved into a cantilever shoulder-wing monoplane with two liquid-cooled inline engines mounted on the wings, nosewheel undercarriage and twin fins, is extraordinarily confused. It reflects the widely differing and fluid opinions which were held regarding the essential requirements of aircraft procurement. The matter was complicated by major changes in the leadership of the Luftwaffe, the Technical Office, and the aircraft industry.

The Technical Director of Heinkel, Heinrich Hertel, moved to the corresponding post at Junkers. His successor at Heinkel was Robert Lusser, who had until then led the design office of BFW. Lusser, who knew only too well the performance limitations of the existing destroyers, attempted to achieve the maximum possible performance with the engines available for this class of aircraft.

After the Western campaign of 1940, when the Office was amenable to ideas, Lusser presented suggestions for a destroyer which essentially represented a further development of the He 119 concept of 1936. This aircraft, equipped with a pair of linked DB 601 engines in the fuselage, had been designed and built to meet the fast bomber specification of 1934-35. It had failed at the time due to the unavoidable separation of the tail gunner from the two other crew members, the restricted bomb-bay due to the engine installation, and the planned surface cooling system. Since the destroyer was to be a two-seater, the first two objections no longer applied, and as the layout certainly offered a minimum drag solution, *i.e.* maximum speed, the Office warmed to the project. However, firing guns through the twin three-bladed propeller presented very serious difficulties, and the configuration would not really allow the machine to be a combination bomber/reconnaissance aircraft. No suggestion was ever made that it could be used as a night-fighter. In this form, *i.e.* with twin engines in the fuselage, work on the project continued until mid-1941.

Within the Technical Office there were influential individuals who wanted to see the development capacity existing at Heinkel exploited to produce a combination fast bomber/destroyer. The standard configuration with wing-mounted engines offered advantages for this purpose, and also made possible the aircraft's use as a night-fighter, and in August 1941 it was decided that this was the only layout which would be considered further. When the Office informed Ernst Heinkel that the project on which the company had worked for so long would not be considered for series production, he dismissed his technical director Robert Lusser. Milch, who was Secretary of State and had become Reichs Air Minister in the meantime, then entrusted Lusser with the task of developing the Fi 103 flying bomb, later known as the V 1, at the Fieseler works in Cassel.

While the prototype aircraft were being prepared, it became clear that the engines for which the machine had been designed would not be available in time. This dashed the hopes of superior performance compared with other types which were already flying, and there was no longer any real point in building the aircraft as a destroyer, but the calculated performance suggested the idea of converting it into a bomber weighing not more than 15 or 16 tons, slotting in between the Ju 88 and the proposed bomber B. A new name was invented for it: Arbeitsbomber (work bomber). Preliminary terms of reference were drawn up; they were dated 22 July, 1942.



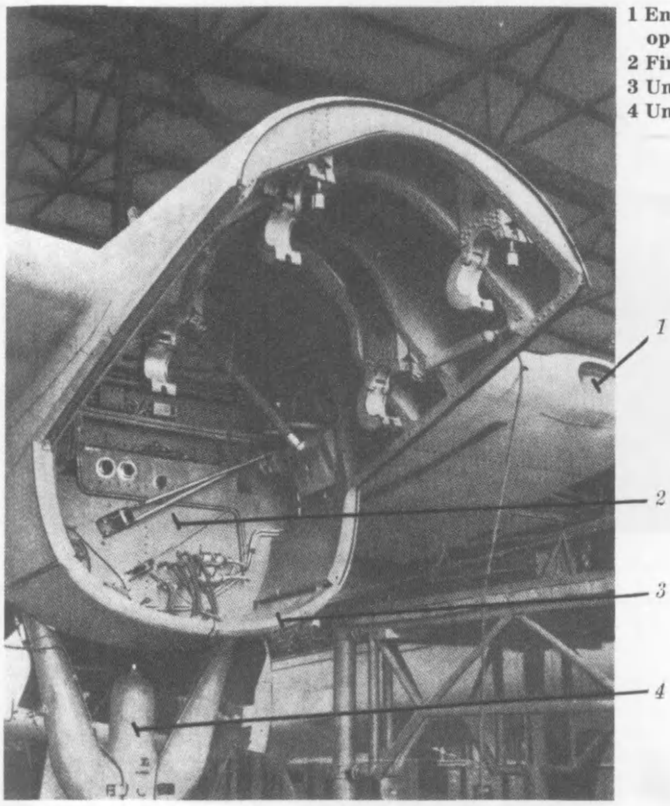
Heinkel He 219 night-fighter

Wingspan	18.5 m
Length	15.5 m
Wing area	44.5 sq m
Empty weight	8,350 kg
Equipped weight	11,000 kg
All-up weight	13,500 kg
All-up weight (max)	15,200 kg
Two Daimler-Benz DB 603	1,560 hp at 7,400 m

The Heinkel works at Marienehe, and the town of Rostock, where most of the Heinkel workforce lived, were attacked and severely damaged by night bombers, but nevertheless the test aircraft were completed in a remarkably short space of time. First flights showed that the machine had acceptable flying characteristics, although further testing indicated that the twin fins had to be enlarged (twice) and that the fuselage needed to be almost a whole metre longer to ensure adequate longitudinal stability. That was too much for a weekend, as had been done with the Fokker D V11 in 1917, but the works manager did it in ten days, for a bonus of 10,000 RM.

In terms of structure and suitability for series production the He 219 was a logical, soundly-based design. The wing had a spar at the 37 per cent chord point, which continued through the fuselage. The secondary spar at the 70 per cent chord point was attached to the fuselage sides. The front part of the wing from the leading edge back to the main spar formed a rigid, large-volume torsion box devoid of large apertures.

New features included the nosewheel and the engine mountings. The latter con-



1 Engine air-inlet opening
2 Firewall
3 Undercarriage door
4 Undercarriage

Heinkel He 219. The new form of engine mounting, completely different from the standard type.

sisted of a fabricated shell instead of a tubular framework, and formed a strong integral unit with the engine nacelle and the wing. The twin-wheel main undercarriage units retracted backwards into the engine nacelles, so that the wheels ended up aft of the mainspar.

The radiators were annular in form and were mounted around the engine gearbox, which necessitated an extension to the propeller shaft. It was planned that the DB 603 engine would be fitted into the Fw 190, the Ju 388, the Me 410, the Ar 440 and other aircraft, and for this reason it had to be interchangeable to the maximum possible extent with the Jumo 213 and other engines. In an effort to eliminate the expense and time wastage involved in developing new engine designs, a plan was drawn up to create a standard power plant, so that all engines in the 1,000 to 2,000 hp class could be paired with all the aircraft. The different type of engine attachment in the He 219 necessitated fairly major modifications if this was to be achieved.

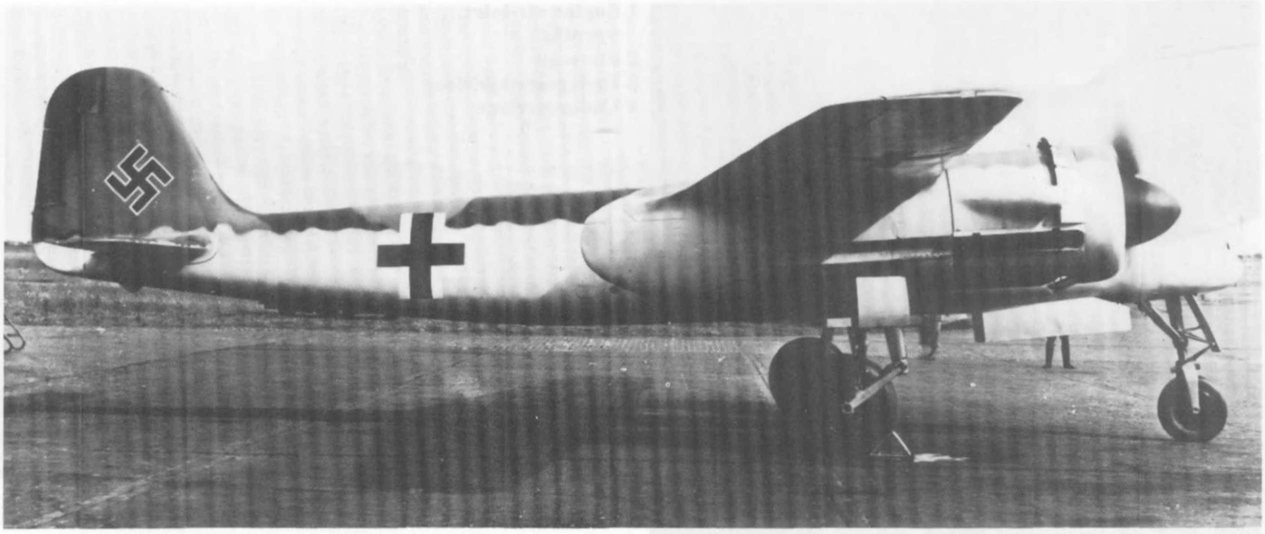
The cabin was located forward of the propellers, in contrast to other twin-engined bombers or destroyers. This was permissible as the aircraft was designed for ejector seats, even though it did not fulfil the requirement for a revolving seat for the radio operator, a feature which the General of the night fighters had vigorously championed at first.

Locating the cabin forward of the propellers offered the advantage that the pilot could not be blinded by exhaust flames, searchlight reflections from the propellers, or muzzle flames from the guns, which were mounted a long way aft below the fuselage. The armament of the two-seat night-fighter consisted of:

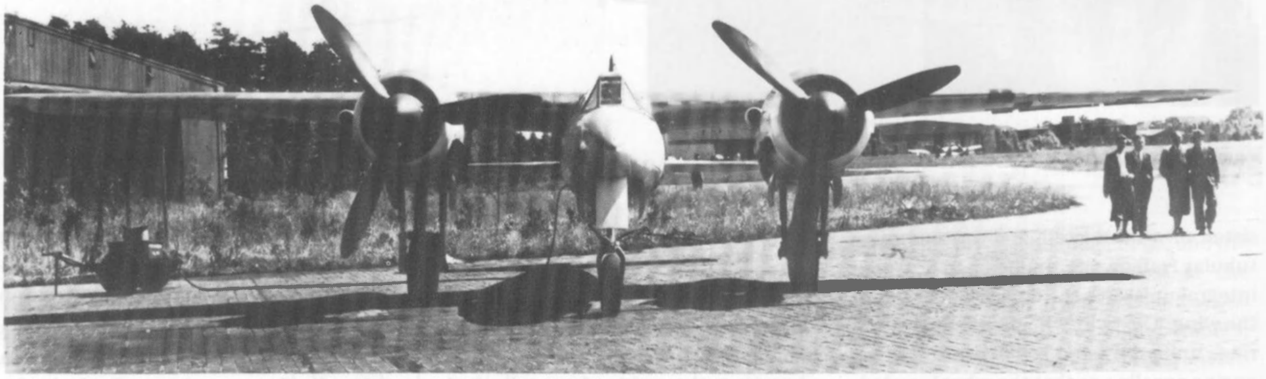
Two MG 151/20 machine-guns in the wing root,
Two MK 103 cannon in the weapons compartment,
Two MG 151/20 machine-guns on the fuselage underside,
Two MK 108 cannon angled upwards.

The forward armament of MK 103, MK 108 and MG 151/20 was interchangeable, depending on which types were available. The night-fighter antenna array was changed regularly to keep pace with developments in radar, which was in constant flux.

The V-machines were put into operational service in June 1943, and they turned in a good performance. A series of comparative flight tests against the Ju 188 night-fighter also showed the superiority of the He 219. A production rate of 100 units per month was planned, but series production got off to a slow start after a series of unfortunate events. By the beginning of 1944 only 26 machines had been delivered. At the end of the programme when production of all piston-engined aircraft of this class was halted, around 250 aircraft had been built. During this period everyone in authority had attempted to force the aircraft into a different mould, and Heinkel had done his best to fulfil all demands in an attempt to keep the machine alive. B- and C-versions were planned as fighter-bombers with remote-controlled twin MG 131 machine-guns in the tail; later a manned tail turret was designed, out of concern that the periscope might not be approved. But none of this saw the light of day.



Focke-Wulf Ta 154, largely built of wood.



The Focke-Wulf Ta 154

Focke-Wulf, in the person of Kurt Tank, made an earlier attempt at a twin-engined fighter in 1936-37 with the Fw 187, as has already been described. He was forced to convert his design from a single-seater to a two-seater, but it proved impossible to fit a rear defensive weapon without major modifications. It is likely that the Fw 187 failed because it could not compete with the Bf 110, even though the 110 was designed for a completely different application.

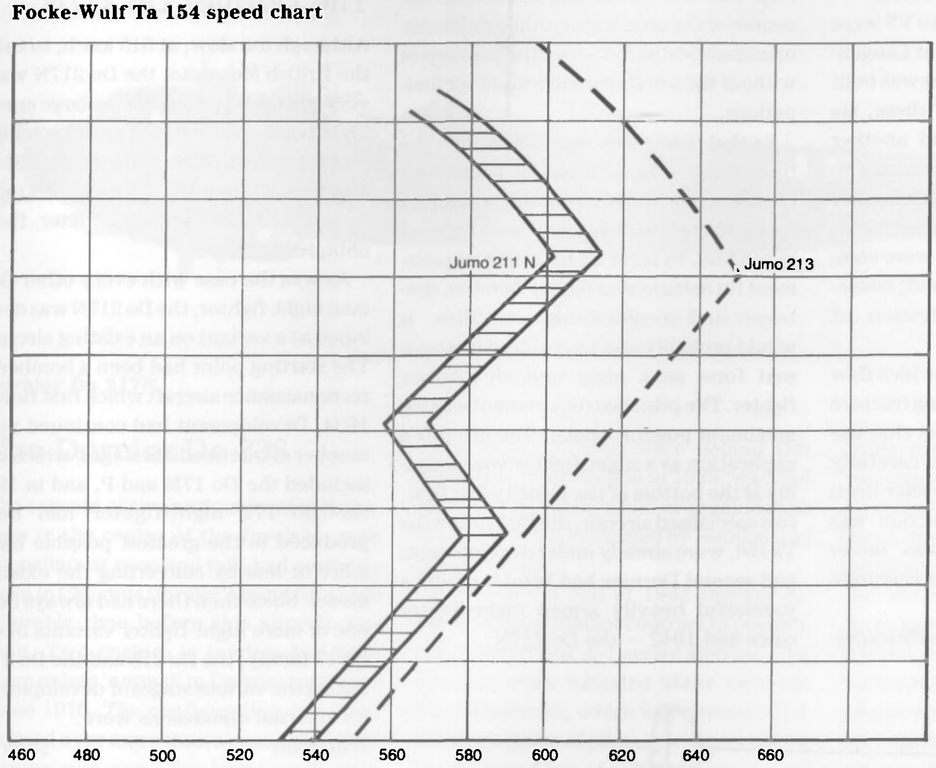
In 1942 Tank, undeterred, returned to the idea of a twin-engined fighter aircraft without defensive capability, built as far as possible of wood, and designed to accept the Jumo 211 engine, which was available in large numbers. The Technical Office had awarded contracts to a number of companies for experiments in the use of wood in place of duralumin, sparked off to some extent by the success of the de Havilland Mosquito reconnaissance aircraft. Focke-Wulf was granted a contract to build an entire aircraft, the Ta 154.

Less than one year later, on 1 July, 1943, a well-proportioned shoulder-wing aircraft, the Ta 154, was ready for its first flight. In its external dimensions the machine did not differ markedly from existing destroyers. Its final all-up weight was also about the same, in spite of the fact that the Ta 154 carried no defensive armament. The weight disadvantage was the price which had to be paid for the use of timber, with its lower specific strength, in such a highly loaded aircraft. Wood was used to the maximum possible extent in the airframe of the Ta 154, including even the front section of the fuselage. Apart from the engines, engine cowlings and undercarriage only the landing flaps, ailerons, elevators and rudder were made of metal. The wing was a two-spar design, with the main spar at 23 per cent chord and the rear spar at 70 per cent. The wing upper surface, which was a stressed skin structure, was designed to absorb a large proportion of the bending forces. The problem of transferring severe, concentrated loads using timber construction was side-stepped by building the wing as a one-piece box structure mounted above the fuselage.

In contrast to existing destroyers the Ta 154 had a nosewheel undercarriage, whose undeniable advantages were to some extent nullified by the higher weight, the difficulty of providing a full-view cabin (for horizontal bomb dropping) and potential severe damage if the noseleg should fail. The pilot sat on an ejector seat, with his knees in the plane of the propellers.

It was planned to install two MG 151/20 machine-guns and two 30 mm MK 108 cannon. Accommodating four heavy weapons in fuselage of pure wood construction, whilst meeting the requirements for weapons maintenance and interchangeability, called for considerable courage and

Focke-Wulf Ta 154 speed chart

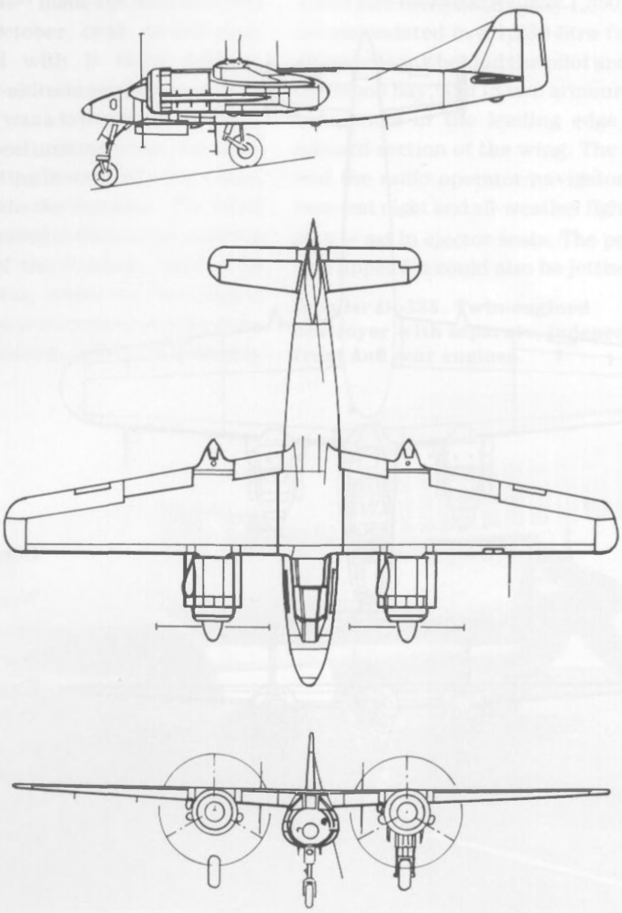


Focke-Wulf Ta 154

Wingspan	16.3 m
Length	12.6 m
Wing area	32.4 sq m
Equipped weight	6,900 kg
All-up weight	8,460 kg
Two Junkers-Jumo 211N	1,110 hp

skill on the part of the designer. Plans were also drawn up for a later version with the front section of the fuselage in sheet metal.

Right from the start the aircraft exhibited good flying characteristics, no doubt due in part to its clean, streamlined form and its low tailplane location. An initial contract was granted for 250 of the night-fighter version. In fact the aircraft was never intended to be built purely as a night-fighter. The schedule drawn up by Focke-wulf and dated 18 June, 1943, *i.e.* two weeks before the first flight, foresaw a large number of variants, some of them to be produced in parallel, some of them in sequence. The machines were to be built at three production centres in Poznan, Schlesien and Thüringen, starting in January 1944, and reaching maximum production of 500 aircraft a month in the summer of 1945. According to this plan the Ta 154 was first to be built as a day fighter with a wooden nose section, in single-seat and two-seat forms. Not until mid-1944 was the night-fighter to be introduced, with a metal front section. The Jumo 213 was intended to supersede the 211 gradually in autumn 1945. A fighter-bomber version was also planned, along with increased span and extended fuselage versions. However, this programme was completely



unrealistic, and never even started.

The first seven aircraft, VI to V7 were built in the Focke-Wulf works at Langenhagen near Hanover. A O-series was built by Ago at the same time. Of these, six machines were destroyed and another severely damaged during an air attack on the factory on 5 August, 1944. A further aircraft was lost in a landing accident. Three or four of the V-aircraft were combined to form a night-fighter unit; consequently, there was no question of systematic testing at Rechlin.

The first production aircraft, which flew on 13 June, 1944, suffered a wing fracture on the 28th, in spite of the fact that the machine's structure had been carefully stressed. The cause was said to have been a faulty glue mixture. Production was immediatley halted, and was never resumed, although the accident was probably not the sole reason.

It seems likely that the Luftwaffe leadership was not too concerned about the demise of the programme although Reichsmarschall Göring did not let the matter rest without the usual reproaches and recriminations.

By that time a new star had risen in the firmament of the twin-engined destroyer class. Dornier had been granted a contract for an aircraft with two engines arranged in tandem, to meet a Luftwaffe requirement for a single-seat fighter-bomber, destroyer and reconnaissance machine. It would probably also be required in a two-seat form as a night and all-weather fighter. The principal requirement was for maximum possible speed. The aircraft's application as a night-fighter was probably at the bottom of the priority list; first, two specialised aircraft, the He 219 and the Ta 154, were already under development, and second Dornier had been building a successful heavily armed night-fighter since mid-1942 — the Do 217N.

The Dornier Do 217N

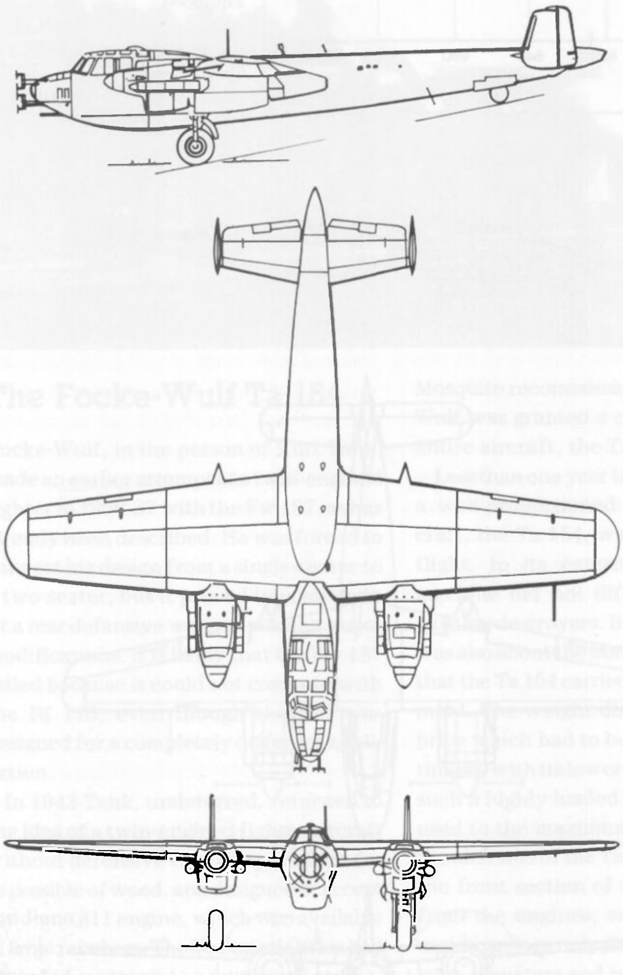
Although too slow, at 515 km/h, to catch the British Mosquito, the Do 217N was a very good weapon against the large enemy night bombers, with its forward machine-gun armament of four 20 mm MG 151/20 and four 7.9 mm MG 17, to which up to four MG 151/20 were added later, firing obliquely upward.

As was the case with every other German night-fighter, the Do 217N was developed as a variant on an existing aircraft. The starting point had been a bomber or reconnaissance aircraft which first flew in 1934. Development had continued via a number of intermediate stages, which had included the Do 17M and P, and in 1940 the Do 17Z night-fighter had been produced in the greatest possible haste more or less by converting the existing model. Since then there had always been one or more night-fighter variants in the Do 17 family, the Do 215 and the Do 217, during the various stages of development. Its external dimensions were:

Wingspan	18 m
Length depending on cabin version	15.8 to 16.5 m
Wing area	55 sq m

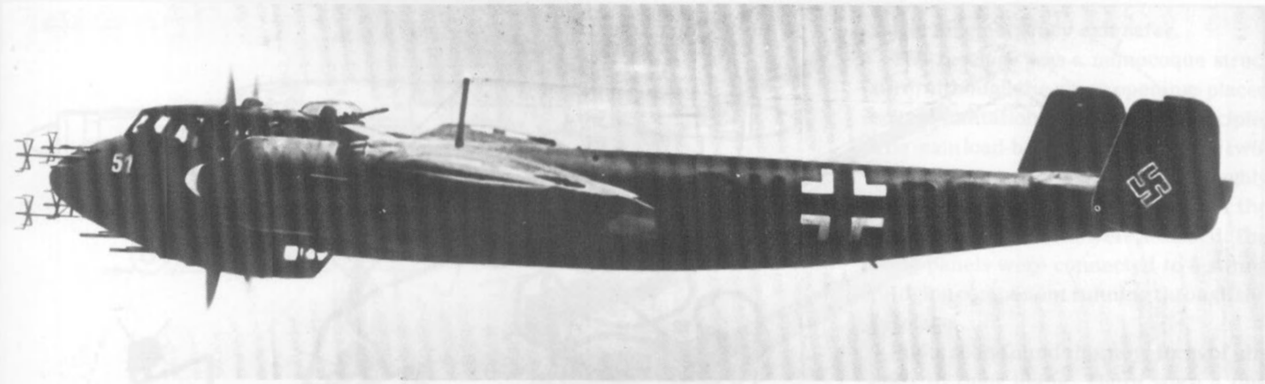
and they remained unchanged until the Do 217, but the all-up weight of the Do 215B grew from the original figure of approximately 7 tons to virtually 9 tons as a result of demands for increased range, better equipment and more powerful armament. Although the landing wing loading was still below 115 sq m, the aircraft's dimensions were enlarged slightly for the more heavily armed and better equipped Do 217. By now the weight had risen to more than 13 tons.

There seemed to be little point in continuing development of this type of aircraft in view of the enemy's technical developments. Thus the path was clear for a decisive move towards the Dornier Do 335.



Dornier Do 217N

Wingspan	19.0 m
Lenght	18.5 m
Wing area	57.0 sq m
Engines	Two DB 603A
Take-off power	1,285 kW (1,750 hp)
Combat power	1,110 kW (1,510 hp) 5,700 m
Airframe weight	10,300 kg
All-up weight	13,200 kg
Armament	4 × 20-mm-MG 151/20
	4 × 7.9-mm-MG 17
	4 × 20-mm-MG 151/20 oblique



Dornier Do 217N.

The Dornier Do 335

The concept of two engines located in tandem in the centre of the fuselage, with propellers at nose and tail, had certainly been in Claudius Dornier's mind for a considerable time before this aircraft was built. Two engines in tandem had been more or less 'normal' in Dornier seaplanes since 1916. The configuration had been refined over more than a dozen different designs, and even a few land aircraft were built with the layout.

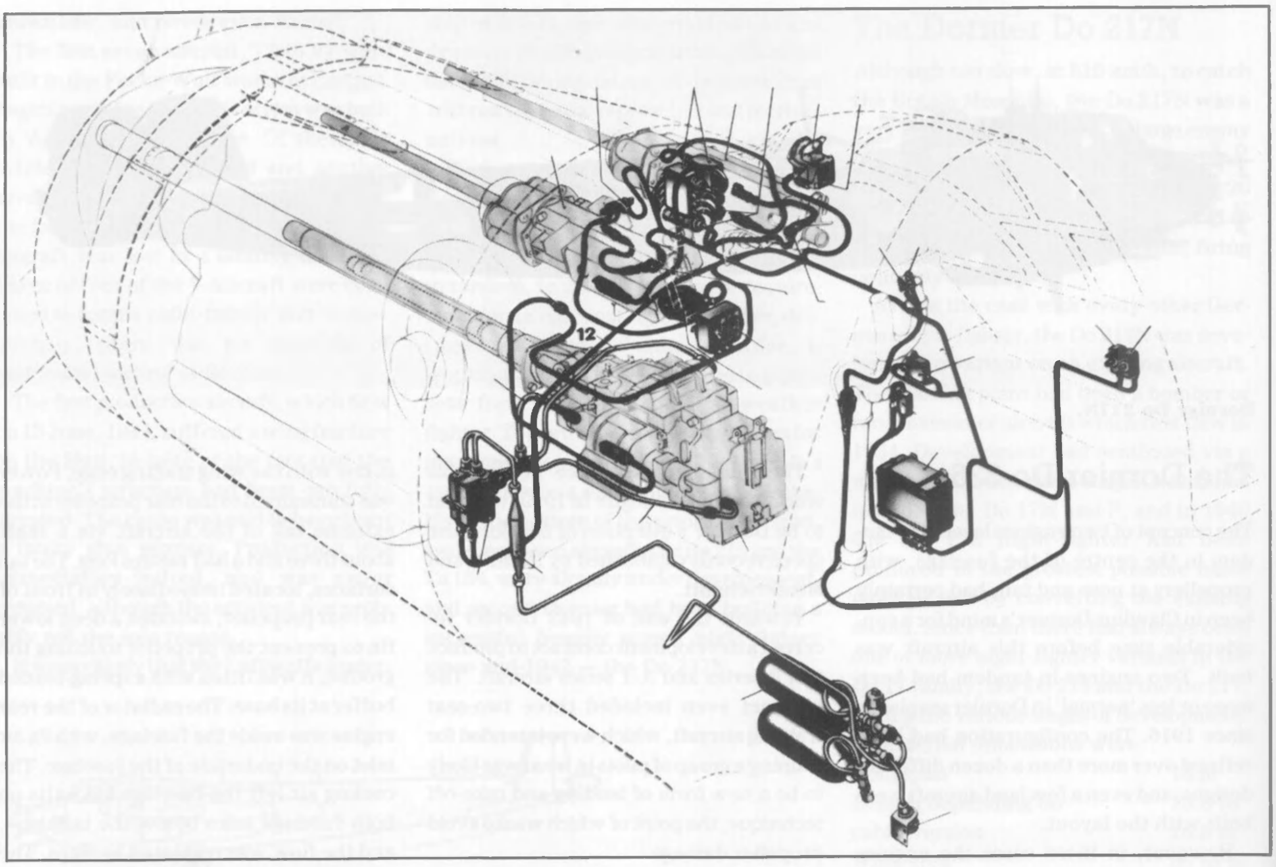
However, in these cases the engines were installed back to back with the propellers mounted directly on the output shafts, except in the case of the four-engined Do 26, a postal/long-distance reconnaissance flying-boat. In this case the rear propellers were driven via a remote shaft. For Dornier then, it was only a short step to the constuction of a single-seat fighter based on these principles. The only points to be cleared up were the possible problems connected with take-off and landing. To this end Dornier had a small test aircraft built.

The initial driving force behind this work, which had begun in 1939, was said to be Dornier's intention of breaking the speed records established by Heinkel and Messerschmitt.

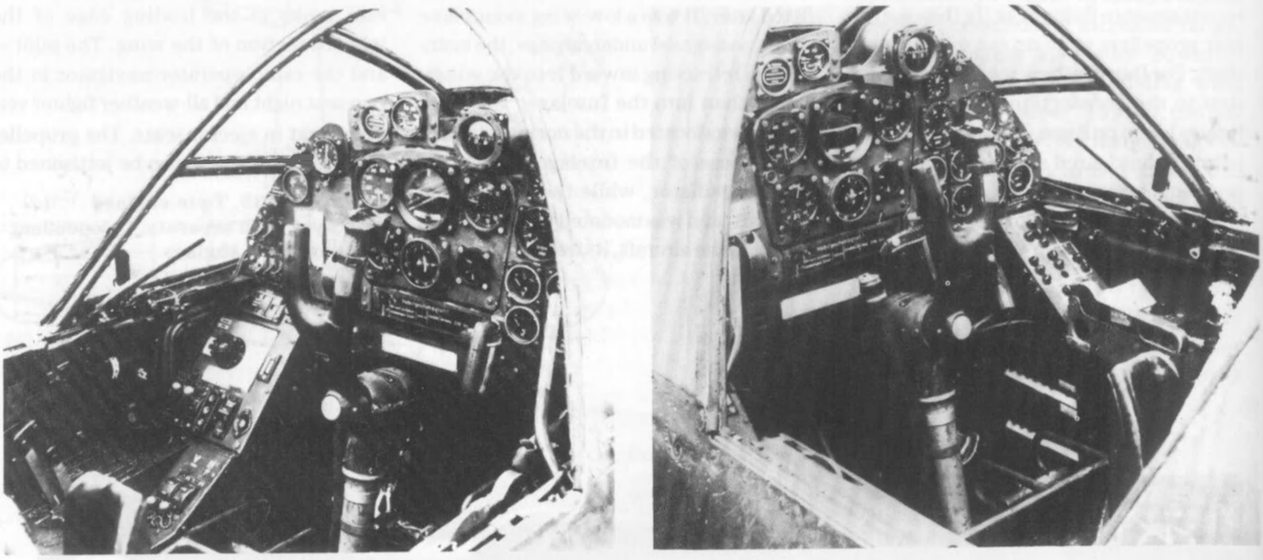
Towards the end of 1942 Dornier received a development contract to produce test 0-series and A-1 series aircraft. The contract even included three two-seat training aircraft, which were intended for training a group of pilots in what was likely to be a new form of landing and take-off technique, the point of which was to avoid propeller damage.

Hans Dieterle[27] made the aircraft's first flight on 26 October, 1943. At this stage it was fitted with D 603A engines, although high-altitude engines were to be fitted later. It was a low-wing monoplane with a nosewheel undercarriage, the mainwheels retracting inward into the wings, rather than into the fuselage. The front engine was located in the normal position in the nose of the fuselage, behind an annular radiator, while the rear engine faced aft, and was mounted just behind the centre of the aircraft, its front end roughly in line with the wing trailing edge. Power was transmitted to the rear propeller at the extreme tail of the aircraft via a shaft about three and a half metres long. The tail surfaces, located immediately in front of the rear propeller, included a deep lower fin to prevent the propeller touching the ground; it was fitted with a spring-loaded buffer at its base. The radiator of the rear engine was inside the fuselage, with its air inlet on the underside of the fuselage. The cooling air left the fuselage via exits on both fuselage sides below the tailplane, and the flow was regulated by flaps. The 1,850-litre fuel load (roughly 1,350 kg) was accommodated in a 1,230-litre fuselage-mounted tank behind the pilot and above the bomb bay, and in two armoured 310-litre tanks in the leading edge of the inboard section of the wing. The pilot — and the radio operator/navigator in the two-seat night and all-weather fighter version — sat in ejector seats. The propeller and upper fin could also be jettisoned to

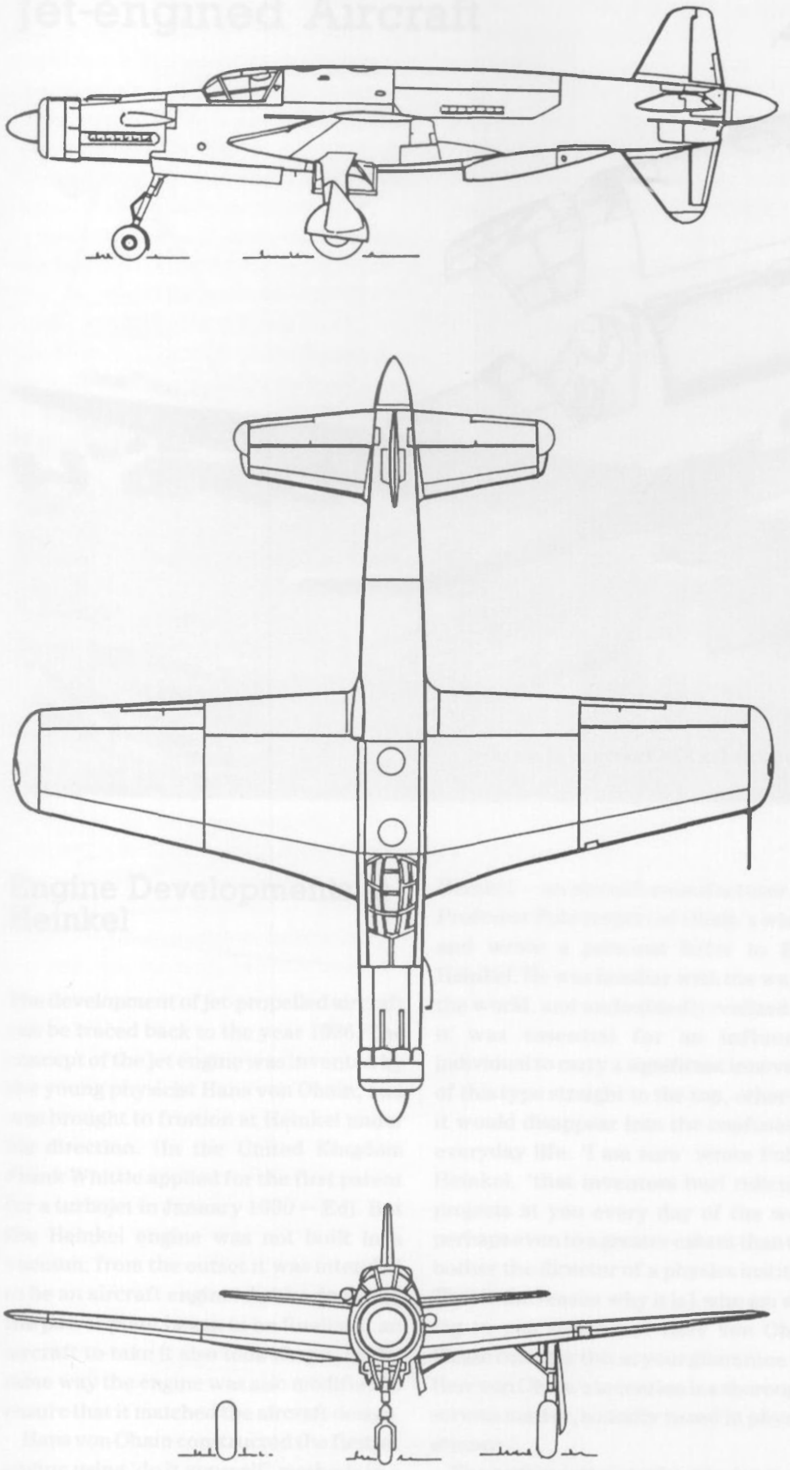
Dornier Do335. Twin-engined destroyer with separate, independent front and rear engines.



Dornier Do 335. Fuselage-mounted guns: one 30 mm MK 103 cannon (Rheinmetall-Borsig), two 20 mm MG 151/20 machine-guns (Mauser).



Dornier Do 335. Instrument panel.



Dornier Do 335

Wingspan	13.8 m	Armament	Two MG 151/20 machine-guns, one MK 103 cannon
Length	13.85 m		
Wing area	38.5 sq m		
Equipped weight	7,260 kg		
All-up weight	9,510 kg		
Two Daimler-Benz DB 603A	1,500 hp at 5,700 m		

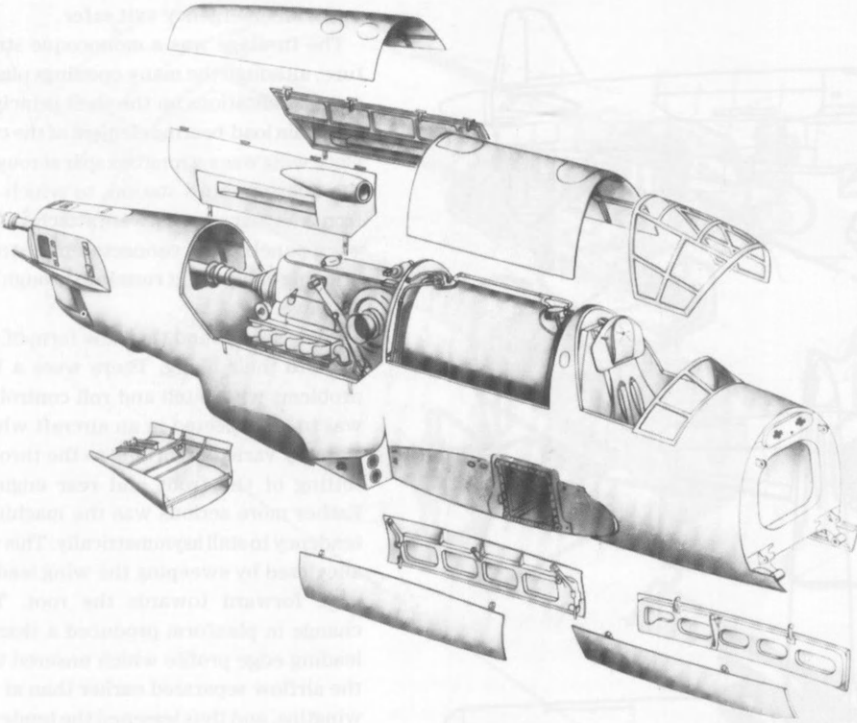
make an emergency exit safer.

The fuselage was a monocoque structure, although the many openings placed severe limitations on the shell principle. The main load-bearing element of the two-piece wing was a strong box spar at roughly the quarter-chord station, to which the front and rear sections were attached. The wing panels were connected to a strong bridging component running through the fuselage.

Pilots soon found this new form of aircraft to their liking. There were a few problems with pitch and roll control, as was to be expected in an aircraft whose stability varied according to the throttle setting of the front and rear engines. Rather more serious was the machine's tendency to stall asymmetrically. This was alleviated by sweeping the wing leading edge forward towards the root. This change in planform produced a sharper leading edge profile which ensured that the airflow separated earlier than at the wingtips, and thus lessened the tendency to drop a wing. There were still complaints about excessive aileron control forces in September 1944.

The armament of the A-series consisted of a 30 mm MK 103 motor-cannon and two 20 mm MG 151/20 machine-guns mounted above the front engine; much more substantial weapons than those fitted to the Bf 109G and K single-engined single-seat fighters which were in use in 1943-44. Nevertheless the machine's fire power seemed to be on the low side for a destroyer which was almost three times as heavy as the Bf 109G. A B-series was planned, with two additional 30 mm MK 103 cannon in the wing, or, to be more precise, in front of the wing; in order to preserve the integrity of the box spar the guns projected a long way foward. The B-series was never built, and in fact the A-series was not built in large numbers, although after the He 219 had been cancelled the Heinkel factory was intended to take up production of the Do 335.

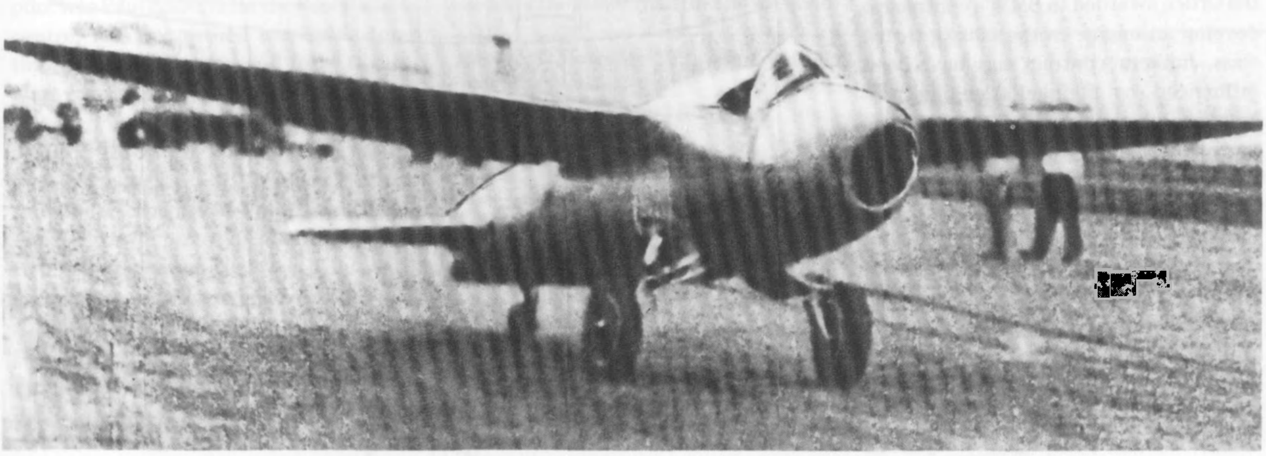
At the end of May 1944 nobody knew whether or when the He 219 would be finally cancelled. The Reichsmarschall did announce the death sentence, but Ernst Heinkel requested in a memorandum dated 15 June that this decision should be reviewed; he spoke of a discussion at Rechlin on 13 June in which the order was given that 'the He 219 must not be cancelled'. The position regarding test aircraft for the He 219 was just as bad as for the Do 335, not to mention production aircraft. The



Do 335 V2 was destroyed in an accident, V6 by a direct bomb hit. At Heinkel things were no better. One thing was certain: the development of fighter and combat aircraft powered by piston engines and airscrews was at an end; the next aircraft would have jet propulsion.

Dornier Do 335 fuselage structure.

Jet-engined Aircraft



Heinkel He 178. The first aircraft with a jet engine.

Engine Developments at Heinkel

The development of jet-propelled aircraft can be traced back to the year 1936. The concept of the jet engine was invented by the young physicist Hans von Ohain, and was brought to fruition at Heinkel under his direction. [In the United Kingdom Frank Whittle applied for the first patent for a turbojet in January 1930 — Ed]. But the Heinkel engine was not built in a vacuum; from the outset it was intended to be an aircraft engine. As the design of the power plant began to be finalised, an aircraft to take it also took shape. In the same way the engine was also modified to ensure that it matched the aircraft design.

Hans von Ohain constructed the first jet engine using 'do it yourself' methods in a car workshop in Gottingen. The unit had a radial compressor (*i.e.* it had a relatively large diameter, as did the engine built at Heinkel).

Ohain selected his partner with what we can only call a sure instinct; he did not choose an aircraft engine company, despite the fact that his professor, R.W. Pohl, and probably everyone else, recommended that route. Instead he opted for Heinkel — an aircraft manufacturer. But Professor Pohl respected Ohain's wishes, and wrote a personal letter to Ernst Heinkel. He was familiar with the ways of the world, and undoubtedly realised that it was essential for an influential individual to carry a significant innovation of this type straight to the top, otherwise it would disappear into the confusion of everyday life. 'I am sure' wrote Pohl to Heinkel, 'that inventors hurl ridiculous projects at you every day of the week, perhaps even to a greater extent than they bother the director of a physics institute. That is the reason why it is I who am writing to you instead of Herr von Ohain. Please consider this as your guarantee that Herr von Ohain's invention is a thoroughly serious matter, soundly based in physical science.'

The engine and aircraft were developed in the strictest secrecy, even from the Air Ministry. Today, some 50 years on, it is impossible to imagine a more apposite machine than the He 178 for the task it had to undertake. A pair of machine-guns on either side, and it would have made a fine, small fighter. The engine was intended to produce a thrust of 600 kg on the ground, corresponding to the thrust of a 2,000 hp engine and propeller at 720 km/h. The aircraft was allowed to fly for the first time on 27 August, 1939, when the engine had been developed to the point where it was producing 450 kg thrust. But the attention and excitement which Heinkel had expected was not forthcoming. It was only five days to the start of the war, and the Luftwaffe leadership had other matters to worry about than new developments. In any case, the Air Ministry had by now been concerned with jet engines for some time; BMW had been granted a contract at the beginning of 1938.

Engine Development under the Direction of the Technical Office

There was a need to gain a clear picture of the most practical configuration and size of engine and airframe, and how they were to fit together, and to this end BFW received a contract to make studies in co-operation with the firm of BMW. At this time the only possible use for the jet engine was thought to be in fighter aircraft, and it seemed obvious that BFW, which was

building the standard Bf 109 fighter, should be entrusted with the work.

The outcome of these studies was a suggested layout for a twin-engined aircraft, whose weight and thrust would be slightly greater than the He 178 which was then under construction. But the power was to be divided between two instead of one engine. The small size of the engines suggested that they should be installed in the wings, with the spar built round them. In spite of the size of engine recommended, the Office awarded to BMW a contract to develop an engine in the 600 kg thrust class. Junkers' contract may have been influenced by Heinkel's engine programme which aimed at rather more powerful engines, intended for a new fighter aircraft with twin engines.

BFW proposed an aircraft with two BMW engines rated at 600 kg thrust, and the proposal was received by the Office in June 1939. The machine was a low-wing monoplane with unswept wings. Wing sweepback had not yet been considered as a means of raising the critical Mach number. The first wind-tunnel tests on swept wings, made at the Gottingen aerodynamic test institute, provided no results until Christmas of the same year.

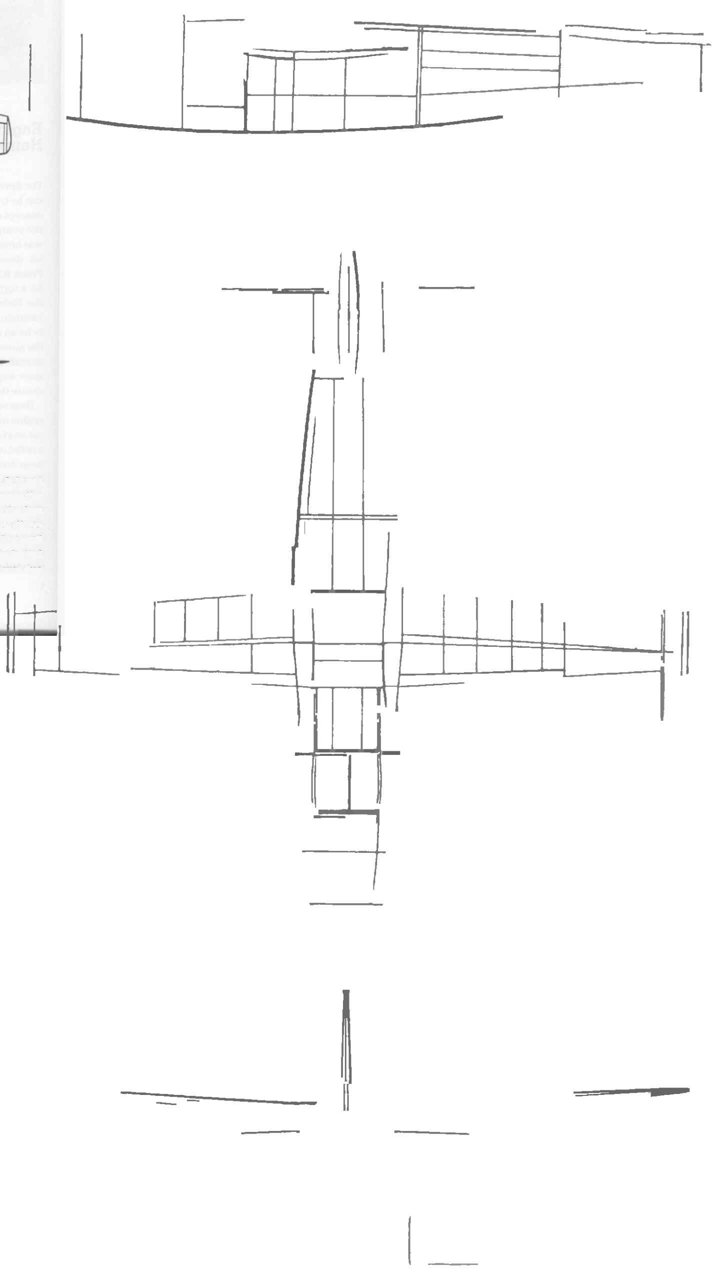
Work continued on the project for a year; there was no great hurry, as the engines were far from being ready. A new proposal, with the engines slung below the wing, was presented in the spring of 1940. The increased weight of the engines was countered by swinging the outboard wing panels aft, and thus shifting the centre of lift back to the centre of gravity. This avoided the necessity of redesigning the entire wing centre section, undercarriage, fuselage-wing junction, etc. The result was a wing which was swept back by about 15 degrees outboard of the engine. This was not a genuine swept wing, which was the great aerodynamic advance of the forties, although early in 1940 the company began an extensive series of experiments on greater sweep angles, using both high- and low-speed wind tunnels. At the time the power of the jet engines was not sufficient to drive the aircraft into the speed range in which sweepback begins to become effective. Nevertheless it was a step in the right direction.

This project represented the real start of the development of the Me 262.

During the period in which the Me 262 was taking shape, Heinkel worked on an aircraft with similar objectives: the He 280. The layout and external dimensions were virtually identical to those of the Me 262. Propulsion was by means of two engines suspended under the wing at about one third of the semi-span, although the 'Provisional technical terms of reference for fast fighter aircraft with jet engine', laid down on 4 January, 1939, only provided for one jet engine. It is not clear whether the similarity between the two projects was connected with the fact that Robert Lusser, who had been director of the Messerschmitt design office until the spring of 1939, was by now technical director at Heinkel, or whether it was due

Heinkel He 178 V1

Wingspan	7.20 m
Length	7.50 m
Wing area	9.1 sq m
Equipped weight	1,620 kg
All-up weight	2,000 kg



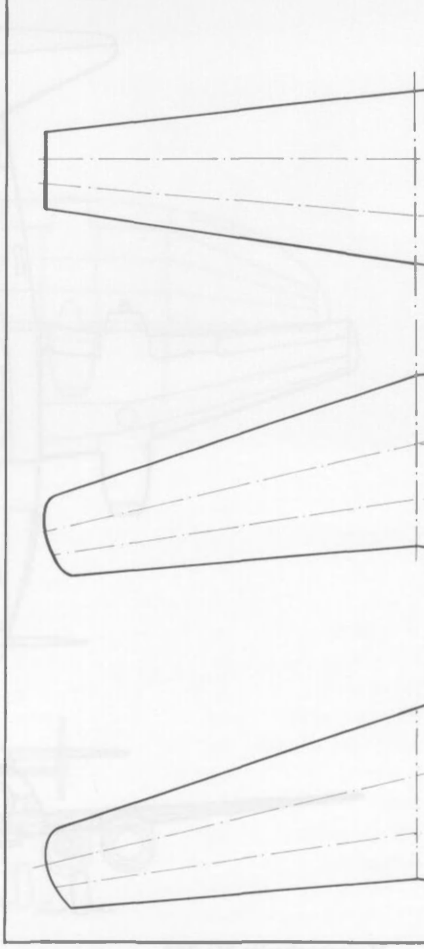
to the Office's influence, or whether the role which the aircraft had to fulfil dictated its configuration. The project for the machine with engines slung under the wing (eventually to become the Me 262), was proposed in May 1940, while the Heinkel aircraft was completed in late summer 1940, albeit minus engines.

Since the power plants were not ready, the He 280 was first flown, on 22 September, 1940, as a glider fitted with dummy motor nacelles, towed by an He 111. The pilot was Paul Bader from the Rechlin test centre. This unpowered test flying continued for six months, and forty flights were completed. When the HeS 8 engines intended for the He 280 were producing a static thrust of 600 kg, they were installed in the aircraft. The machine first flew under its own power on 3 April, 1941. The V2 and V3 prototypes followed, and Heinkel was granted a contract to build six further aircraft. However, the engine was so unreliable that several prototypes were fitted with Argus tubes, the power unit designed for the Fieseler Fi 103 flying bomb, later known as the V 1 (Vergeltungswaffe — retribution weapon — No. 1).

Neither of the other engines had yet reached anything like maturity, and in fact they were so far from being usable that the Me 262 was fitted with a Jumo 210G piston engine — the power plant used in the first Bf 109 — in the nose, in order to get the machine into the air. In this form the aircraft was flown for the first time on 18 April, 1941, in the hands of Fritz Wendel. These flights could not possibly have had any technical significance, as the airflow from the propeller would have had a major influence on stability and tail surface flow. In fact one major problem with the jet-powered version failed to show up at all. In its initial form, with an orthodox tailwheel undercarriage, the aircraft proved to be unable to get its tail off the ground on the take-off run without the assistance of the slipstream from the propeller. It subsequently became necessary to undertake a major conversion to a nosewheel undercarriage.

In the meantime the BMW 003 jet engines had been improved, and now produced a thrust of 460 kg, and the Me 262 flew for the first time with these engines installed on 25 March, 1942, although the piston engine was still in place. This proved to be an extraordinary foresight, for both BMW engines failed soon after take-off on the first flight. One year after the He 280 had first flown under its own power, the Me 262 still could not manage it. After this near disaster the BMW 003 engines underwent major modifications, which cost almost a year.

Messerschmitt Me 262. Wing planform development.



Heinkel He 280 V1 with Heinkel engines.

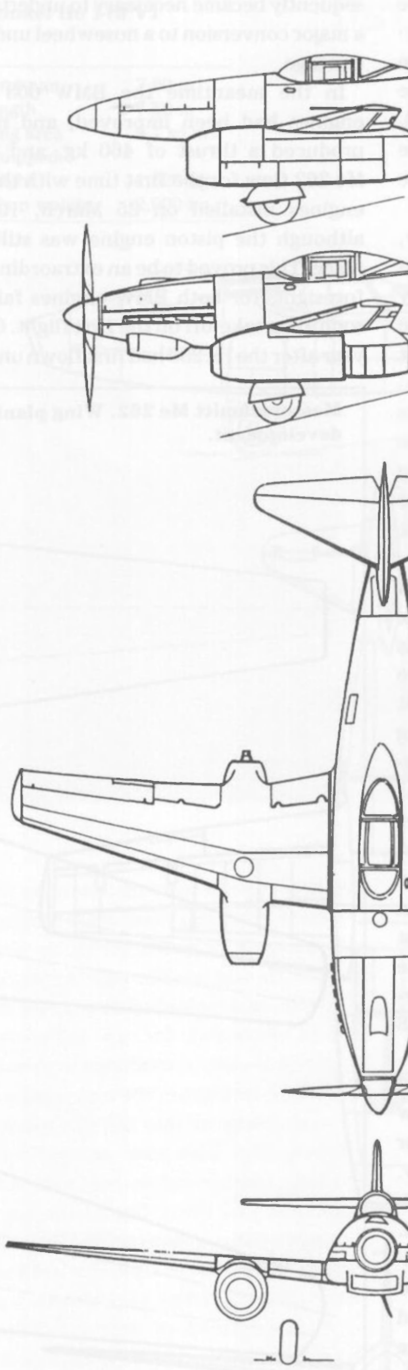
The Jet Aircraft

During this period the Junkers engine works were developing the Jumo 004 turbojet. Similar in principle to the BMW unit, but differing in detail and slightly larger and heavier, it had already attained a thrust of 600 kg — the figure required by the contract — on the test bench. Flight testing began in mid-March 1942, using the Me 210 converted into a flying test bed. When the engines had proved themselves reliable, they were installed in the Me 262 V3 in place of the BMW engines, once the necessary modifications had been made. The first flight took place on 18 July, 1942, again in the hands of Fritz Wendel, but this time without the piston engine. The first flight lasted 12 minutes, and was followed by a second of 13 minutes on the same day. Immediately after these flights the root wing chord was increased. The aircraft had shown that it could not lift its tail from the ground, but the pilot had overcome the problem by waiting until a good speed had built up on the ground, then pressing the brakes momentarily. However, the aircraft maintained its excessive angle of attack — producing high levels of drag — over the major part of the take-off run, which was already much longer than normal due to the characteristics of the jet engine. This idiosyncratic take-off technique subsequently led to an accident when the machine was first test-flown at Rechlin.

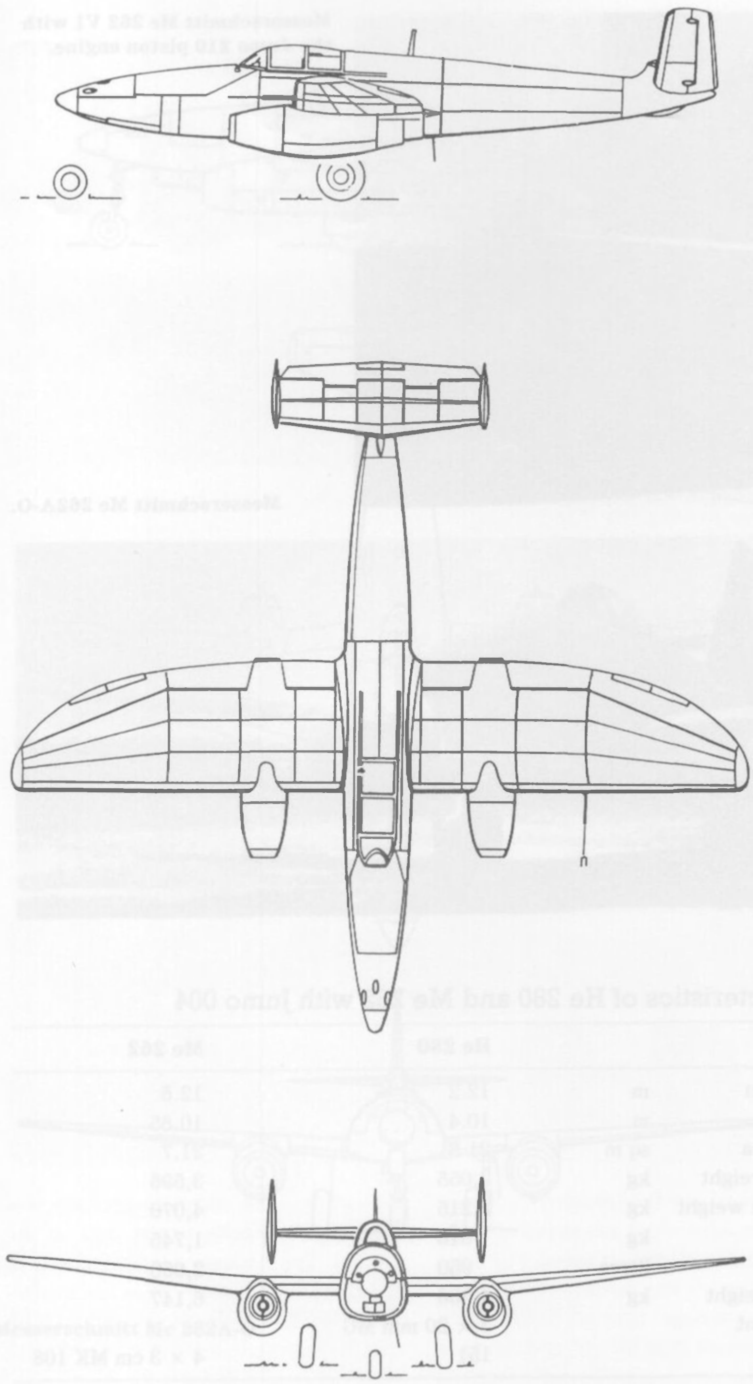
On 1 October, 1942, the Me 262 V2 flew for the first time, also fitted with Jumo 004 engines, followed in April 1943 by the V4. On 22 May, 1943, the General of the fighter pilots, General Galland, flew this machine. Galland had to report to Milch, the Secretary of State for Air and General Inspector of the Luftwaffe, and his views on the aircraft and its implications were included in a letter dated 25 May, 1943 (excerpts):

'1. The aircraft represents a massive advance, which ensures us an enormous lead over the enemy if they stay with piston engines for any length of time.
2. In flight the airframe makes a very good impression.
3. The engines are completely convincing, except on take-off and landing.
4. The aircraft opens up completely new tactical possibilities.'

Following on from this, Galland suggests:



Messerschmitt Me 262 V1 in the form in which it flew for the first time, with two BMW 003 turbojets and one Jumo 210 piston engine. Top: After conversion to Jumo 004 turbojet, now minus the piston engine.



Heinkel He 280

'The Fw 190D is under development, and will inevitably be the equal of the Me 209 in all respects. Neither type will be superior to enemy machines in terms of performance, especially at altitude. The only advances that we can expect are in the areas of weapons and speed.

For this reason:

a) Cease work on the Me 209 type.

b) Convert all fighter units to Fw 190 with 801
and Fw 190 with DB 603
or Jumo 213.

c) The design and production capacity freed by these measures should immediately be used for the Me 262.'

A few days later approval was granted to produce the Me 262, even though the precise configuration of the aircraft had not yet been decided. The Luftwaffe demanded a nosewheel undercarriage, but such a machine was not ready to fly until 26 June, 1943, and even then it was only a temporary installation, as the nosewheel was not retractable.

Origins of the Heinkel He 280

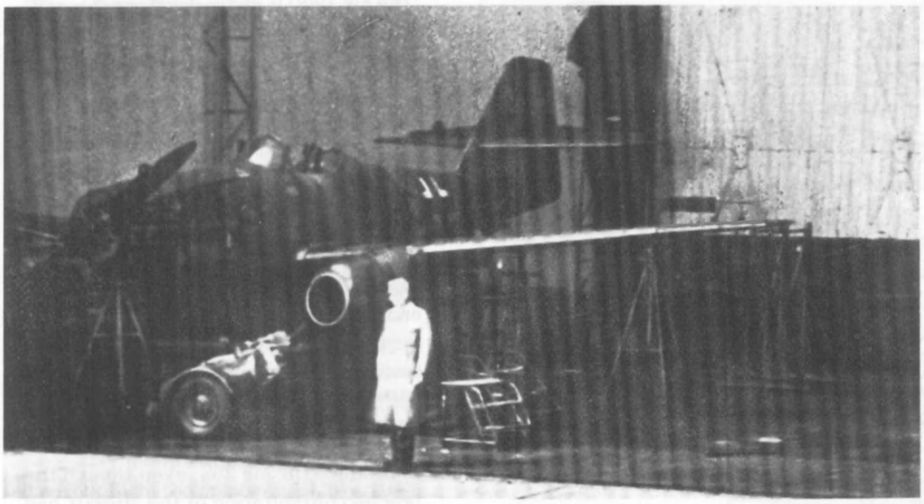
In the summer of 1942 the only serviceable jet engine was the Jumo 004, as the HeS 8 unit in the He 280 single-seat fighter had not proved reliable. For this reason the He 280 was also fitted with the Jumo engine. The He 280 V6 in this form was taken to Rechlin for testing, and discussions were held on production of an initial run of 300 units, but this was probably not a serious proposition. Heinkel worked very hard at keeping the project alive, in spite of the directive which the Secretary of State and General Inspector of the Luftwaffe sent to him on 15 September, 1942. Under the heading 'Priorities' Milch wrote to Heinkel (abbreviated):

'. . . I must ask you nevertheless to postpone further work (on the 'work bomber'), until the He 177 has reached the stage where it is genuinely ready for active service. In respect of the development work currently in progress, I request the following priority:

1. He 177
2. He 219
3. He 111, altitude tasks
4. He 274
5. He 280, conversion to Jumo TL'

And so the He 280 found itself in last place, and virtually disappeared from the jet-fighter contest.

The weights stated for the Me 262 A-1 are those of a completely developed fighter, in its November 1944 state, includ-



Messerschmitt Me 262 V1 with the Jumo 210 piston engine.

Messerschmitt Me 262A-O.

ing heavy armament, armour and more than twice the fuel of the He 280, whose values are as of December 1942. The projected all-up weight for a revised He 280 with heavy armament was stated as 5.2 tons. Since the two types were virtually identical in terms of external dimensions, it is likely that the only difference in their maximum speed would have been due to manufacturing tolerances.

Characteristics of He 280 and Me 262 with Jumo 004

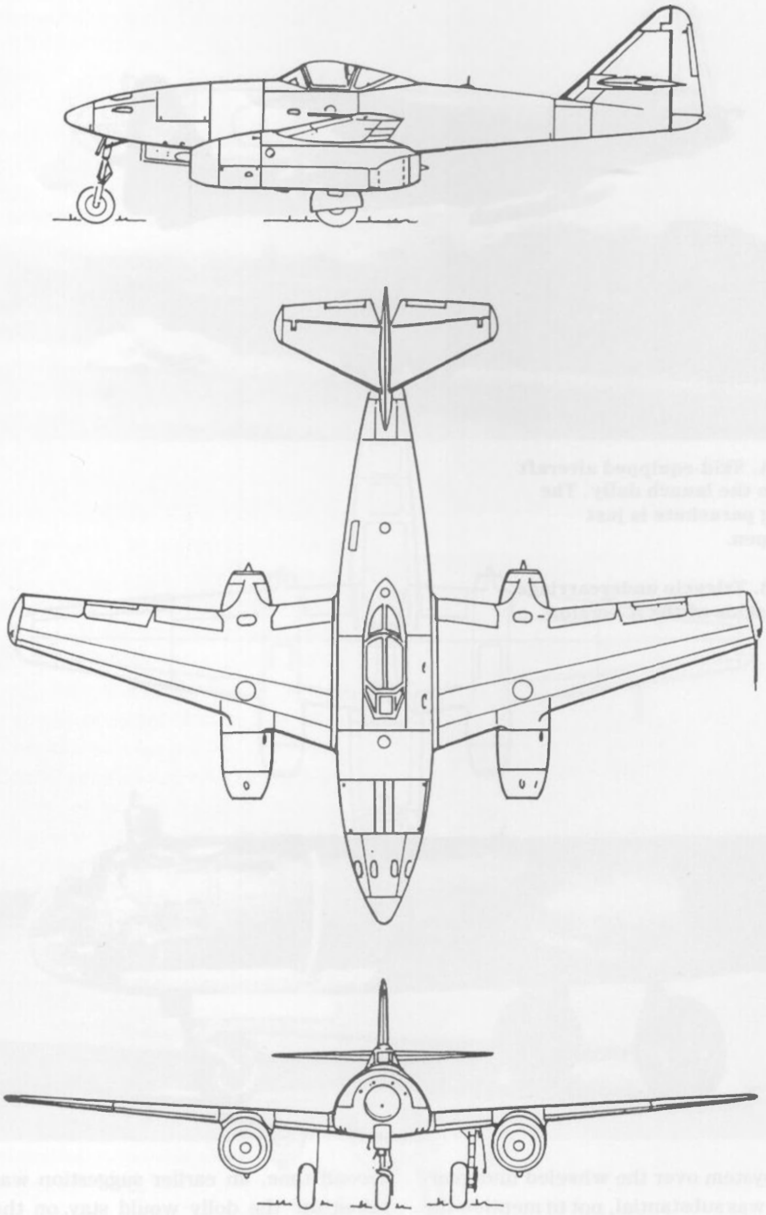
		He 280	Me 262
Wingspan	m	12.2	12.5
Length	m	10.4	10.65
Wing area	sq m	21.5	21.7
Empty weight	kg	3,055	3,596
Airframe weight	kg	3,215	4,070
Fuel	kg	810	1,745
Fuel	litres	950	2,050
All-up weight	kg	4,300	6,147
Armament		3 × 20 mm MG 151	4 × 3 cm MK 108

Further Development of the Me 262

Modifying the aircraft from tailwheel to nosewheel undercarriage was a major operation, necessitating fundamental changes in the fuselage centre section and the wing roots, quite apart from the undercarriage, its attachments and the retracting mechanism. Prototypes V5 and V6 were selected for flight testing with the new undercarriage, so they were out of action for a long period while the conversions were made. In consequence only one aircraft, the V4, was available for test flying at the beginning of November 1943. By January 1944 a further three machines had been completed for test flying. These were part of the zero series, for which contracts had been awarded in July 1942. Gradually the factory completed a sufficient number of aircraft for test flying, but the engines remained the obstacle, as they had not yet reached an adequate level of operational maturity. Even if normal levels of reliability were ignored, they could not be built in large quantities, as they required precious minerals such as chromium, nickel, moblybdenum, etc. in far too great a quantity.

In June 1943 a discussion was held with the Generalluftzeugmeister during which approval was given for a monthly production of 60 units, starting in May 1944. It is likely that this also was at Galland's instigation.

At the end of July 1943 the first American daytime air attacks began on German inland industrial sites. Hanover, and the Continental rubber works in particular, was hit at midday on 26 July. Two days later, also at midday, the Henschel aero engine works at Cassel were attacked, and although many of the enemy forces were



Messerschmitt Me 262A-O

shot down, a large number of German fighters were also lost. In mid-August 1943 Göring announced an immediate increase in fighter aircraft production to 4,000 units per month. Within the industry a figure of 3,500 had been under discussion since June. The only possible means of meeting these demands was to continue building the Bf 109 and Fw 190 on the existing jigs. The idea of withdrawing personnel and abandoning existing jigs, as Galland wanted, seemed to be impossible. The only possibility would have been to halt production of other aircraft, but Hitler was still thinking of a Luftwaffe with an attack capability. When the request for more jet fighters was made, Milch and Goring responded 'that the Fuhrer considers the risk of such a major change to be too great'. Presumably Hitler had little interest in the machines, as he wanted Jabos — Jagdbomber, or fighter bombers — and the Me 262 had always been described as a fighter, which it certainly was.

But it was already too late. The industrial concerns which were vital to fighter production were attacked by day with such ferocity that production dropped instead of rising. The United States Air Force strikes were well planned and accurate, and in an attempt to evade them the production workshops were divided up into small units and moved into caves and abandoned mines. At Hitler's instigation, Goring asked Willy Messerschmitt whether the Me 262 fighter could be used to drop bombs. When he gave Hitler a positive answer, the wind changed. Hitler put his full weight behind the Me 262, even though he was not pushing in the desired direction. His plan was to use the machines to bomb the British and American troop landings, which were expected early in the year. On 5 December, 1943, Hitler informed Goring that it was imperative to have a series of jet fighter-bombers completed by the spring, and he also wanted constant written reports on the state of jet aircraft development.

The Arado Ar 234

The Me 262 was not the only jet aircraft which Hitler was considering; there was also the Arado 234, which was the second jet aircraft under development for the Luftwaffe, after the cancellation of the He 280. Work on the 234 had begun in 1941. Had it not been for the engine delays, the Ar 234 would have flown much earlier, but as it was the V1 flew for the first time on 30 July, 1943, under Flight Captain Selle. V2 and V3 were flying by September.

Originally conceived purely as a reconnaissance aircraft, the Ar 234 would not belong in this book had it not been converted into a night-fighter in the final months of the war. The requirement laid down by the Office in 1941 called for a single-seat unarmed reconnaissance aircraft powered by two Jumo 004s. It was to be faster than enemy fighters, and have a total range of 2,200 km, *i.e.* sufficient to fly over Britain as far as Scapa Flow. This was a formidable task, bearing in mind the high fuel consumption and low power of the jet engines of the time. The aircraft was also required to be capable of taking off and landing from makeshift airfields. It was estimated that a total of 50 aircraft would be produced; hardly a worthwhile order from the industrial point of view. However, since it had such low priority in the overall armament scheme, the machine's development continued without the interference of other departments. The outcome was a shoulder-wing machine with engines slung below the

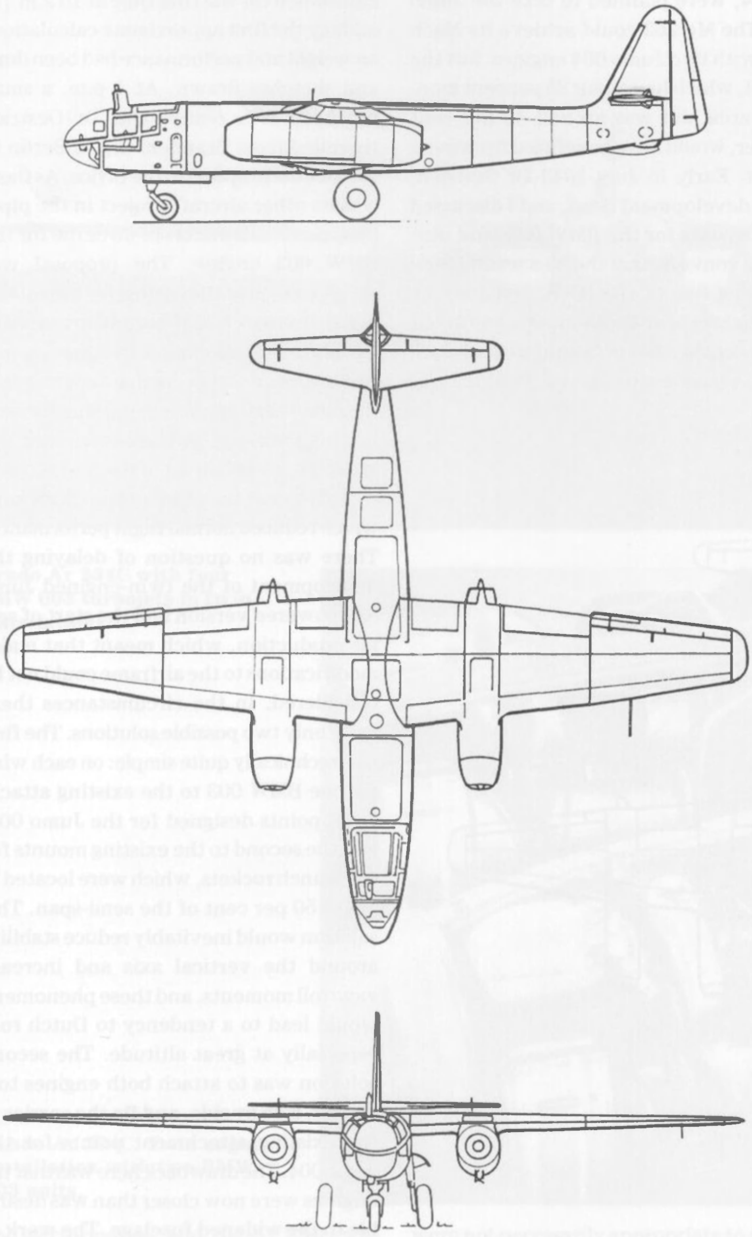
Arado Ar 234A. Skid-equipped aircraft on lift-off from the launch dolly. The dolly's braking parachute is just beginning to open.

Arado Ar 234B. Tricycle undercarriage instead of the skids of the A version.

wings, as on the Me 262, and an almost fully-glazed nose section for the best possible view. There was really no alternative engine arrangement, as the Air Ministry had accepted as standard the engine configuration and attachment which had been developed for, and in parallel with the Me 262. This was to ensure that the engines could be replaced by the BMW 003 engines, which were under development at the same time.

Instead of the usual wheeled undercarriage the Arado 234 was fitted with a retractable central landing skid and two supplementary retractable skids below the engines, in the interests of saving space and weight. Bearing in mind that the fuel amounted to 40 per cent of the machine's all-up weight, and that the power plants and fuel together accounted for 66 per cent, the 2 per cent weight saving of the skid system over the wheeled undercarriage was substantial, not to mention the large amount of space it saved. For take-off the aircraft was mounted on a 'tricycle undercarriage' take-off dolly, which was jettisoned after lift-off, and returned to earth by parachute. The dolly's wheels could be made as large as was necessary, which was of advantage on grass airfields. The dolly added substantially to the aircraft's take-off weight, and this was countered by fitting launch rockets, which would have been needed in any case because of the low take-off thrust of the engines. Taxi-ing and taking off using the dolly was perfectly practical, but on the first two flights the parachutes failed to open, and the dollies were wrecked. This was why there was a delay between the first and successive take-offs. After the take-off dolly parachute failed for the second time, an earlier suggestion was taken up: the dolly would stay on the ground. The necessary modifications to the attachments and release mechanism were completed in three weeks, and from that time a large number of take-offs were made without problem.

In the air the Ar 234 proved to be a complete success from the very first flight. Not one single modification to the airframe was required. Stability, control forces, control response, stall behaviour, everything was faultless; except the behaviour of the engines. On the third flight the V1 was severely damaged in an emergency landing after an engine failure. The engines, throttled right back on the landing approach, had stopped and could not be restarted. Incidentally the skid system proved its worth in this emergency landing on uneven terrain. Further evidence



was provided by V6, which was the first airframe to be fitted with four BMW 003 engines. In an emergency landing it touched down in a cornfield and slid 500 m, through a potato field, through a further cornfield, and through another potato field. The aircraft suffered no damage at all.

The V2, flown for the first time on 13 September, 1943, crashed on its fifth flight on 1 October after an engine fire, killing the pilot, Selle. The test-flight procedure was then halted until succeeding aircraft were fitted with ejector seats. Apart from these two accidents the Ar 234 completed its testing with far fewer 'incidents' than had the Me 262, since the engines had a further year of development behind them by the time the 234 first flew. The second flight of the Ar 234 lasted almost an hour.

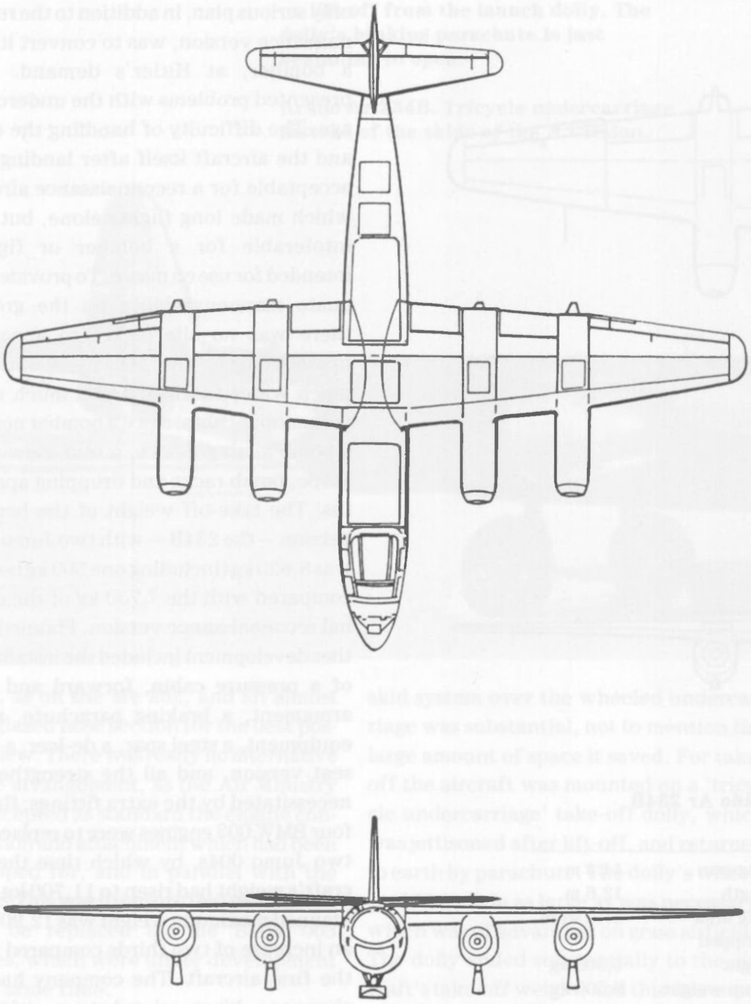
Arado Ar 234B

Wingspan	14.4 m
Length	12.6 m
Wing area	27.0 sq m
Equipped weight	5,300 kg
All-up weight	9,000 kg
Two Junkers 004	900 kg thrust each

As soon as the machine's excellent flying characteristics and high performance became known, suggestions came pouring in from all sides for converting the unarmed reconnaissance machine into an unarmed bomber, a fighter, a reconnaissance machine with rear armament, a destroyer, an armed bomber, a night-fighter, etc. On 23 August, 1943, just four weeks after the first flight, the General of combat pilots, Colonel Baumbach, suggested to Heinkel that he abandon the He 177 heavy bomber and convert the Ar 234 into a fighter. But it all came to nothing. The only serious plan, in addition to the reconnaissance version, was to convert it into a bomber, at Hitler's demand. This presented problems with the undercarriage. The difficulty of handling the dolly and the aircraft itself after landing was acceptable for a reconnaissance aircraft which made long flights alone, but was intolerable for a bomber or fighter intended for use en masse. To provide adequate manoeuvrability on the ground there was no alternative to a normal undercarriage, and this necessitated a much wider fuselage and a much more voluminous cabin, since a bomber needed a bomb aiming device, a rear-view periscope, bomb racks and dropping apparatus. The take-off weight of the bomber version – the 234B – with two Jumo 004s was 8,620 kg (including one 500 kg bomb), compared with the 7,750 kg of the original reconnaissance version. Planned further development included the installation of a pressure cabin, forward and rear armament, a braking parachute, more equipment, a steel spar, a de-icer, a two-seat version, and all the strengthening necessitated by the extra fittings; finally four BMW 003 engines were to replace the two Jumo 004s, by which time the aircraft's weight had risen to 11,700 kg. The planned maximum weight was 12,900 kg, an increase of two thirds compared with the first aircraft. The company had no chance to object seriously to any of these planned modifications and was forced to tackle the engineering problems which they posed. But time ran out, and the majority of the changes were not accomplished before the end of the war. One exception was the installation of four BMW 003 engines in place of the two Jumo 004s.

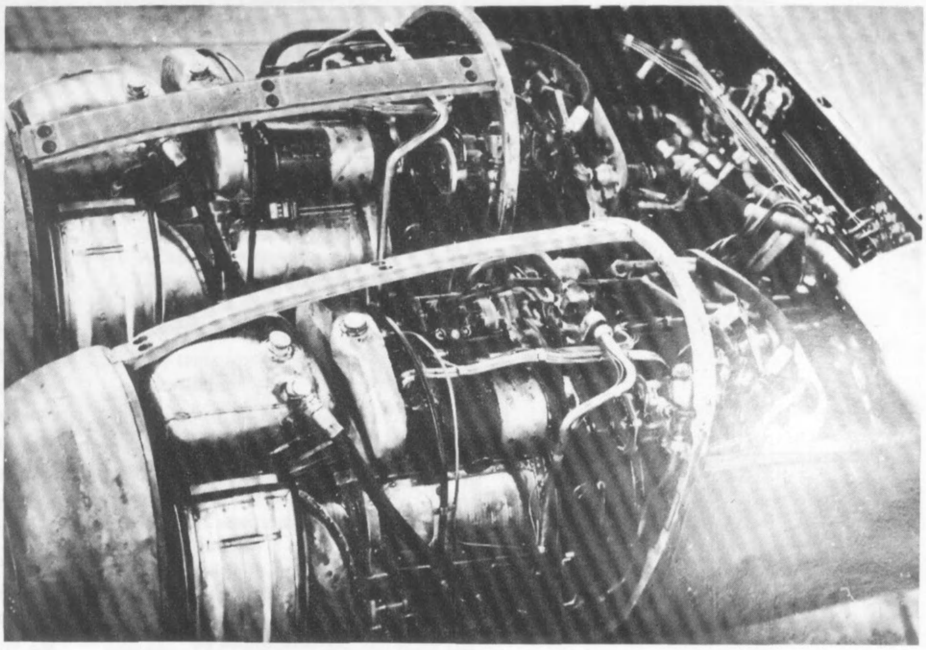
The Ar 234 with four BMW 003 Engines

In the summer of 1943, just over a year after the disaster with the BMW 003 engines in the Me 262 which occurred on 25 March, 1942, modifications and improvements had been made to the BMW unit, and it had now reached and even exceeded its specified thrust. The governor developed by Junkers for the Jumo 004 engine had been adopted to solve the problem of controlling the engine. However, there was now a lack of customers, as both jet aircraft, Me 262 and Ar 234, were planned to take the Jumo 004. The Me 262 could achieve its Mach limit with two Jumo 004 engines, but the Ar 234, which had about 25 per cent more wing area and was around 40 per cent heavier, would have benefitted from more power. Early in July 1943 Dr Oestrich, BMW development head, and I discussed possible uses for the BMW 003, and during the conversation the idea was mooted of fitting two of the BMW units, which were lighter than the Jumo 004 and about 25 per cent smaller in frontal area, in place of one of the Jumo engines. The idea was mentioned for the first time at 10 a.m.; at midday the first approximate calculations on weight and performance had been done and sketches drawn. At 4 p.m. a small brochure was ready, and Dr Oestrich travelled from Brandenburg to Berlin to present the proposal to the Office. As there was no other aircraft project in the pipeline, this was a matter of do or die for the BMW 003 engine. The proposal was received well at the Office, for the intelligence services had reported advances in jet engine development in America and Britain, and it was becoming apparent that the initial performance requirements were not high enough. A bonus was that the greater take-off thrust of the four engines would obviate the need for launch rockets, which reduced normal flight performance. There was no question of delaying the development of the twin-engined Jumo 004 powered version and the start of series production, which meant that major modifications to the airframe could not be considered. In the circumstances there were only two possible solutions. The first was technically quite simple: on each wing fix one BMW 003 to the existing attachment points designed for the Jumo 004, and the second to the existing mounts for the launch rockets, which were located at about 50 per cent of the semi-span. This solution would inevitably reduce stability around the vertical axis and increase yaw/roll moments, and these phenomena would lead to a tendency to Dutch roll, especially at great altitude. The second solution was to attach both engines to a carrier, side by side, and fix the carrier to the existing attachment points for the Jumo 004. The drawback here was that the engines were now closer than was desirable to the widened fuselage. The work of producing the engine fairings for the twin engines was made even more difficult because the Office stated categorically that not the slightest modification was permissible either to the inlet cowls, which were a standard part of the engine, or to the outlet nozzles. These conditions explain the somewhat bizarre shape of the twin-engine nacelles of the Ar 234C. The version fitted with four separate engines did indeed exhibit the expected Dutch roll problem[28]. One of the skid-equipped machines had been selected as the test aircraft for this layout, and when it was damaged after a fire in one outboard engine, the testing programme was halted. The aircraft with the twin engines proved to have satisfactory flying characteristics



Arado Ar 234. Experimental aircraft with four BMW 003 turbojets mounted separately. One of the first skid-equipped aircraft was selected as the test machine.

Arado Ar 234C with four BMW 003 turbojets in twin installations.



Arado Ar 234C. Twin engine installation with two BMW 003 units.

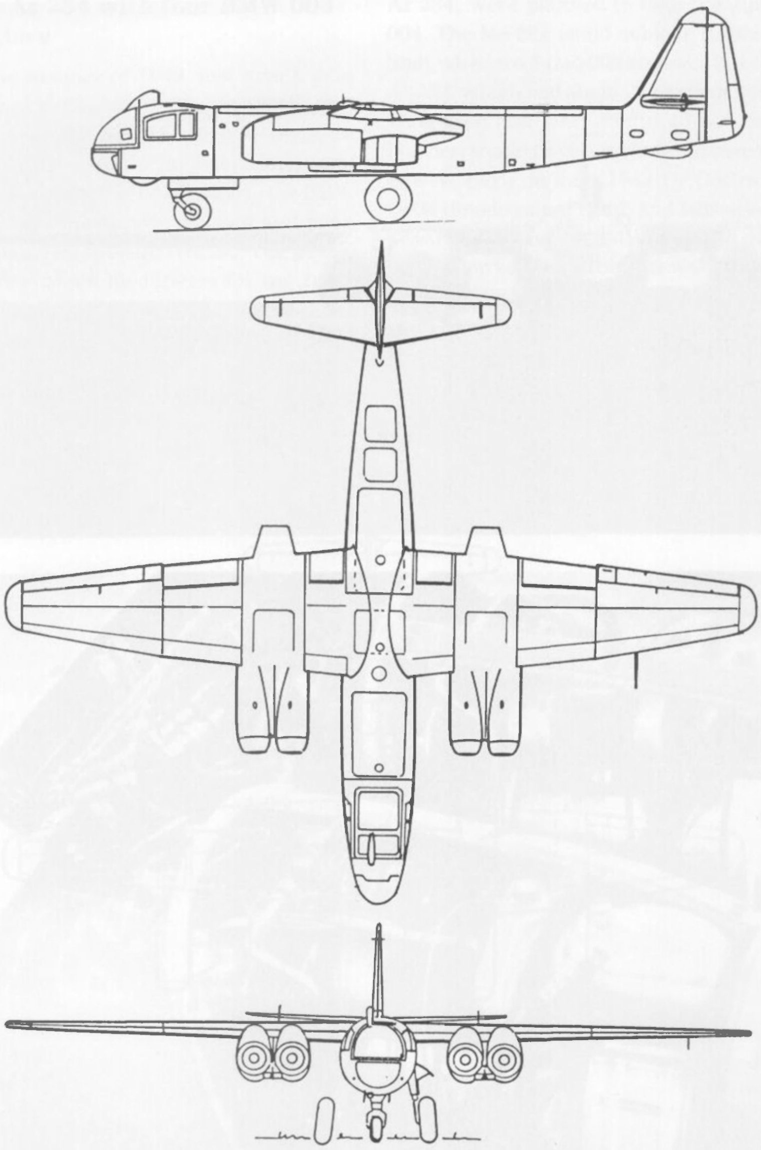
and performance, and the Ar 234C was subsequently included in the long-term plan as the standard version of the aircraft, to be produced after the twin-engined Ar 234B series was finished.

The aircraft failed to achieve the expected top speed of 850 km/h, as Mach number effects set in at 835 km/h at 9,000 m, affecting the handling of the aircraft. The machine's flying qualities had also deteriorated somewhat as no changes had been made to the tail surfaces to counter the effects of the wider fuselage, enlarged cabin and fatter engine nacelles. The first test aircraft had been enthusiastically received, but the later versions attracted criticism from the test pilots at the Rechlin test centre, although they were accustomed to flying qualities which were not necessarily appropriate to an aircraft of this type. Service pilots considered the machine to be as good as ever. After the Air Ministry development expert had flown the aircraft, his verdict was: 'an important advance in aircraft design.'

The Ar 234 at the Front

An indication of the level of quality and reliability of the first prototypes and their Jumo 004 engines which had been attained by early 1944, is that two of the test aircraft – V5 and V7 – still equipped with skids, were removed from testing and transported to the Front, a few days before the invasion early in 1944. On the Western Front it was no longer possible to gather aerial intelligence with any other aircraft.

However, an indication of the circumstances in which such a detachment had to operate, is that of two railway wagons carrying accessories, spare parts and ground equipment such as take-off dolly, take-off rockets, etc: only one arrived at the airfield, with the result that the aircraft could not be used in earnest until 2 August; the first operation then turned out a complete success. One further pointer to the situation was that both aircraft were fired at by their own AA guns, in spite of warnings to all AA batteries by Flight Command. V5 was shot down on 28 August, 1944, in this way. By 13 September the two aircraft had made a total of 31 flights, including transport, personnel transfer and training flights, of which 14 were successful operations covering about 20 hours of flying. The Oranienburg high-altitude



Arado Ar 234C

Wingspan	14.4 m
Length	12.6 m
Wing area	27.0 sq m
Equipped weight	6,400 (6,800) kg
All-up weight	10,500 (11,500) kg
Four BMW 003	800 kg thrust each

flight-test centre, as the long-distance reconnaissance group of the OKL (Luftwaffe High Command) was officially designated, was supplied with four further B-series aircraft. By 30 October the formation had made 38 operations over the Western Front, notching up 50 flying hours.

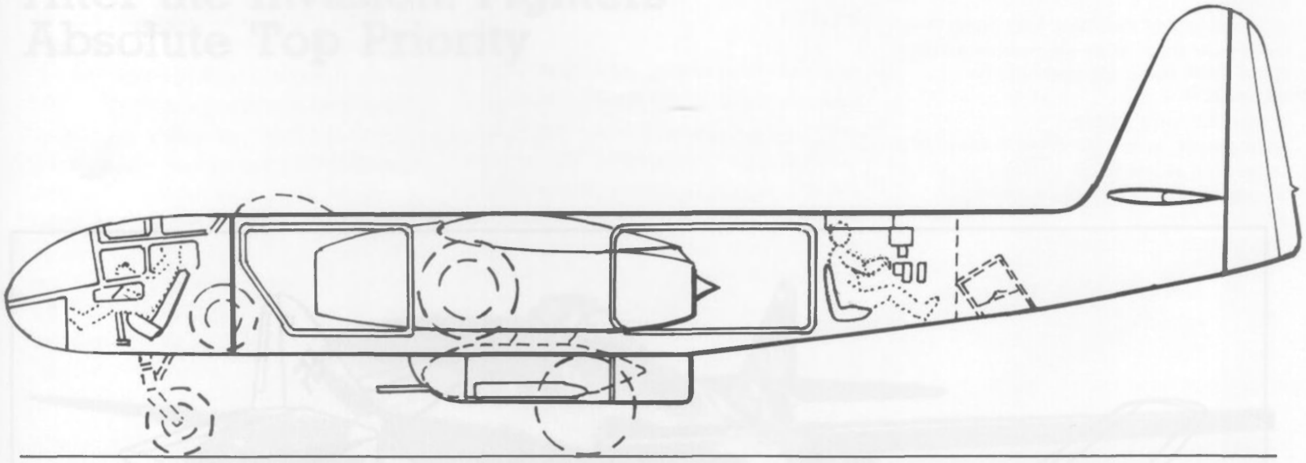
Even though a bomber version was eventually developed in addition to the reconnaissance aircraft, the Chiefs of Staff pressed hard for a night-fighter version powered by four BMW 003 engines and with a two-man crew, who were located in a staggered arrangement, part side by side, part in tandem. They also called for the Nachtigall — Nightingale — which was an improvised night-fighter whose radio operator/navigator was located far from the pilot, in the space occupied by the camera on the reconnaissance machine. In the last few months of the war a small number of B-series aircraft were converted in the workshops of the test station for high-altitude flying at Oranienburg. A total of just over 200 aircraft were built.

The Me 262 as a Bomber

In the meantime further development had been undertaken on the Me 262, although the work had been hindered by continuing differences of opinion on whether the machine was a bomber, a fighter-bomber or a fighter. The pilot's rearward position made the machine unsuitable for horizontal bomb dropping from great altitude. As a fighter-bomber too much of its limited range would have been wasted if it was used at low altitudes. The only application which remained was as a high-altitude pursuit fighter — the task for which the Me 262 had originally been created. But long after this had become obvious, the machine's production as a fighter aircraft was obstructed by Hitler's order to build the Me 262 as a Blitzbomber — lightning bomber. In fact, mass production was not possible in any case until a new version of the Jumo 004 had been developed, which relied less on precious materials. The engine had had to be completely revised to meet this criterion. As late as March/April 1944 no final decision had been made on mass production of the Me 262; it was still a matter for discussion.

The flying characteristics of the Ar 234 had been outstanding from the outset, and since the Ar 232 and the Ar 240 also had good handling, I found that I had acquired a reputation for knowing the secret of this aspect of aircraft design. For this reason

Arado Ar 234B night-fighter version



I suddenly received an order to examine the Me 262 and write a clean bill of health for it, guaranteeing that the design of the aircraft and its aerodynamics were sound, and that the aircraft should be built in series. In other words: the Technical Office was looking for somebody who would help to carry the can. This must have been in late March or early April 1944, as I remember that snow still lay at the edge of the forest in Oberammergau. The episode is mentioned here in order to illustrate that the official, binding contract for large-scale construction of the machine was probably not granted until after this time. Production still stood at 60 units a month.

On 25 May, 1944, the Service Generals and industry leaders held a discussion with Göring, as mentioned elsewhere; the following order concerning the Me 262 was announced:

'a) On the Führer's command, the entire Me 262 production is to be supplied in Jabo (fighter-bomber) form.

b) The testing of the Me 262 and, in particular, the TL [jet engine] testing of the Jumo 004, is to be given top priority above all other test procedures.

c) The stock of Me 262 aircraft at Lärz (Rechlin) for TL testing is to be increased to six.

f) Contracts have been granted for thirty Me 262s, to be used for test purposes.'

A few days later, on 31 May, *i.e.* six days before the invasion, the following announcement was made:

'The designation Jabo (fighter-bomber) is to be cancelled and replaced with Schnellstbomber — maximum speed bomber. The Me 262 is to be used as a tactical aircraft at heights of 3,000 metres, beyond the range of the . . . light anti-aircraft guns.

All departments concerned with implementing this command from the Führer are to concentrate exclusively on this single task: maximum speed bomber.

1. The Me 262 is to be included under the control of the General of the combat pilots (for tactical use).
2. The Me 262 command at Lechfeld is to undertake further testing with the sole aim of preparing the aircraft for use as a maximum speed bomber. Weapons testing for use as a fighter is to be continued in parallel with the above, but to the mimimum possible extent.
3. The tests are to clarify the following questions:

a) Centre of gravity position[29]:
with one 250 kg bomb
or two 250 kg bombs
or one 500 kg bomb
without weapons and without ammunition
with and without 600 litre fuel tank, full and empty

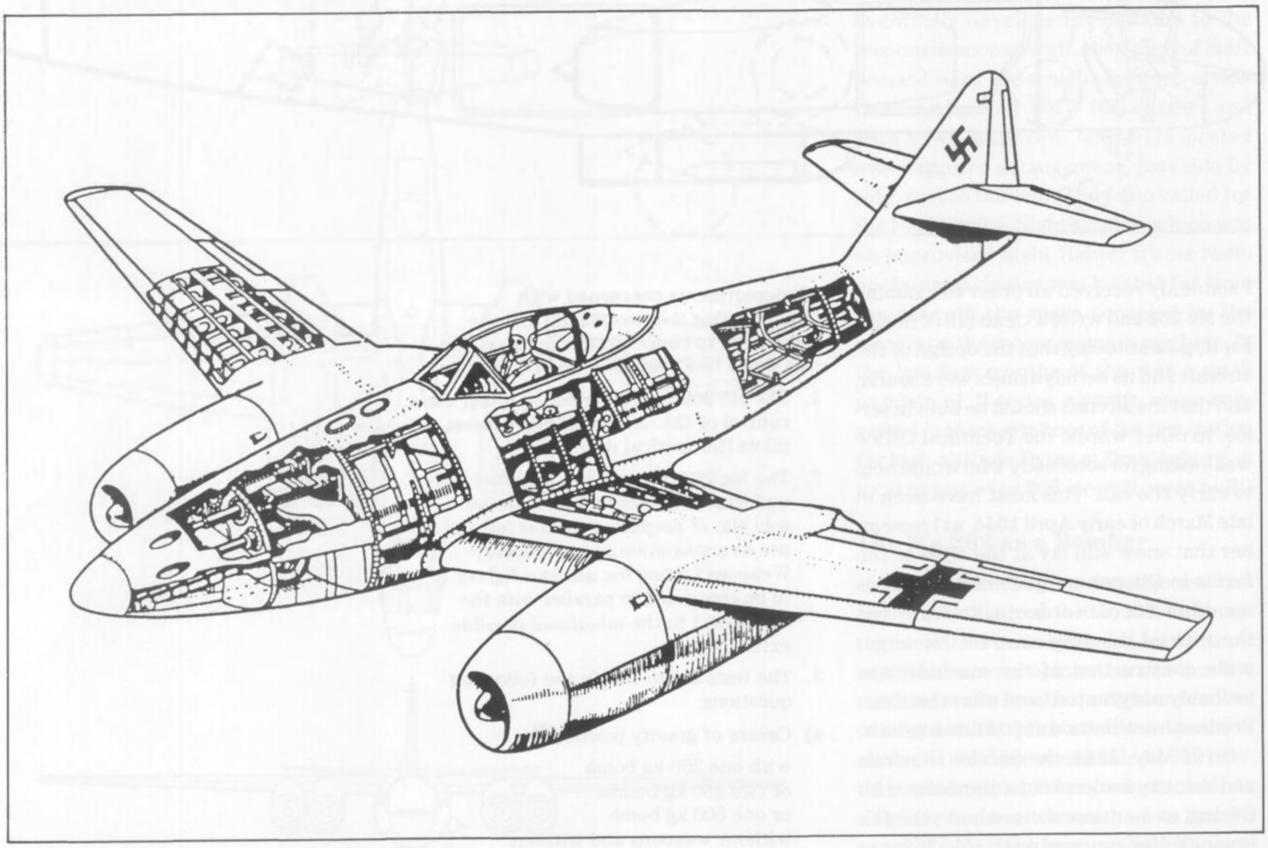
The front armour is to be omitted for this purpose. The centre of gravity tests are also to be made on the aircraft with two weapons and ammunition installed. Final decision on weaponry is for the Herr Reichsmarschall.

b) Sighting:

Test installations of BZA 1 a, BZA 20 and TSA 2 are to be made under consideration of the following requirement: precision aiming of bomb not required; instead large-area target (invasion bridgeheads, port installations).

c) New fuselage centre section:

The Herr Reichsmarschall has awarded Professor Messerschmitt a contract to develop a new fuselage centre section with prone bomb aimer (four 70 kg bombs and possibly Lotfe bomb sight installation); if possible an improvement in the pilot's view from 8 degrees to 25 degrees.'



Messerschmitt Me 262

Wingspan	12.6 m
Length	7.3 m
Wing area	21.7 sq m
Equipped weight	4,120 kg
All-up weight	6,100 kg (fighter) 6,400 kg (bomber)
Two Jumo 004	900 kg thrust each

After the Invasion: Fighters Absolute Top Priority

Messerschmitt Me 262 fighter.

All this occurred before the invasion, and was intended to combat it, but it was all far too late. Once the Channel Coast landing had started, the picture was suddenly altogether different, and top priority went to the fighters. The following is an excerpt from a letter from the 'Fighter Staff' dated 2 July, 1944:

'Matters arising from the discussion with Herr Reichsmarschall on 1 July, 1944

1. On 30 June, 1944, the Führer, wishing to protect the homeland and secure the Front, issued the following orders: fighters absolute top priority; heavy combat aircraft to be cancelled completely. The stock of fighters, destroyers and night-fighters is to be increased to 10,000. This number to include 5,000 new machines, divided up as follows:

3,800 fighters (incl. 500 Me 262)
400 destroyers
500 night-fighters

In addition: 4,700 machines already included in the proposed programme. The shortfall of 300 'fighters' to be made up by increased production of the Ar 234, and if possible introduction of the Me 262 into the fighter sector.

2. Within the fighter sector combat aircraft, Jabos (fighter-bombers) (no new types, only the most useful existing types) and short range reconnaissance aircraft . . . are also to be produced.

3. The reduction in the bomber sector is to be made in order to promote increased fighter production . . .

4. New developments are to be restricted to the utmost extent . . . no modification of aircraft by pilots. Expressed wishes to modify aircraft to be stringently screened. No changes of equipment.'

Only four copies were made of this part of the letter from the Fighter Staff, but the second part was intended for distribution to a larger number:

The programme of 1.7.1944. The Blitzbomber (lightning bomber)

'B. The programme:

1. The following aircraft are cancelled: (list of 20 types, basically large aircraft, but including the Ta 154 and Me 410)

2. The following are to be continued, but to a limited extent: (after four touring and communications aircraft) the He 219, 50 aircraft per month

3. Remaining types:
Me 264: to be brought forward 1 year, not more than 4 per month[30]
Me 163: 100 per month. To be stationed near rocket fuel works[31]
Bü 181: 120 per month[32]
Ju 287: capacity available for 100 per month, materials available for 50 per month. Further decision on this: early 1945 [33]
Me 262: production to be raised to 500 per month in 1944, then raised again to 1,000, of which at least one half in the fighter version [34]
Ar 396: 230 per month[35]
Ju 388: 550 per month[36]
Do 335: 550 per month[37]
Ar 234: 500 per month[38]

C. Development:
1. Ar 432 to be converted to wood construction as far as possible[39] . . .
3. High altitude fighters to be held in abeyance
5. Dual control training aircraft for single-seaters very significant . .'

Only a few days later, on 5 July, 1944, the Reichsmarschall held a further conference, in which only a very small number of aircraft types was mentioned. An excerpt from the Fighter Staff's written report, dated 17 July, 1944:

'A. Enhanced-performance fighter aircraft types for use as fighter-bomber
1. Bf 109: performance with AS motor . . . not sufficient. With additional MW injection the aircraft is too heavy. Not advised for use as fighter-bomber.
2. Fw 190: has achieved speed improvement of up to about 40 km/h fitted with the BMW 801TS (as yet not fully tested), with no significant weight increase. Reasonable equality of performance compared with the normal enemy fighter is maintained when carrying one bomb.
a) Herr Reichsmarschall desires that . . . half of the Fw 190s with BMW 801TS should be produced as Jabo fast bombers.
b) Ta 152 with Jumo 222 to be tested as potential improvement on the single-engined Otto fighter for the long term.

B. Blitzbomber (lightning bomber)
1. Me 262:
a) Report on developments concerning technical shortcomings by 8.7. All undercarriage problems must be rectified.
d) The matter of Messerschmitt management must be cleared up
2. Ar 234:
a) Herr Reichsmarschall commands that the same priority be given to the final lightning-bomber version as to the Me 262.
b) Feasibility of carrying three 250 kg

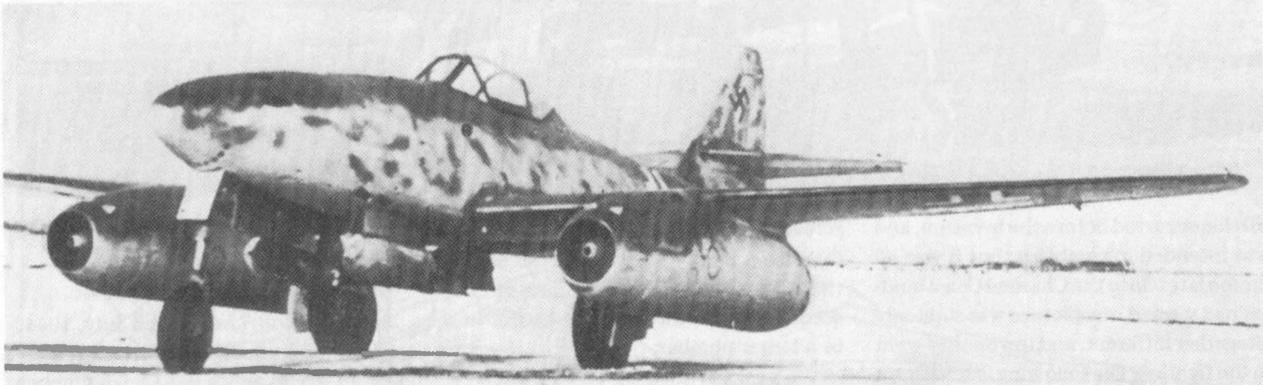
bombs with two Jumo 004s to be examined.
c) Feasibility of installing four Jumo 004s to be examined, as an alternative solution if the BMW 003 engines should be delayed.
3. General information:
a) In general terms Lightning-bombers not to be used at low level; to be flown as far as possible beyond range of enemy machine-guns, *i.e.* not below 3,000 m.'

The Me 262 in its Final Form

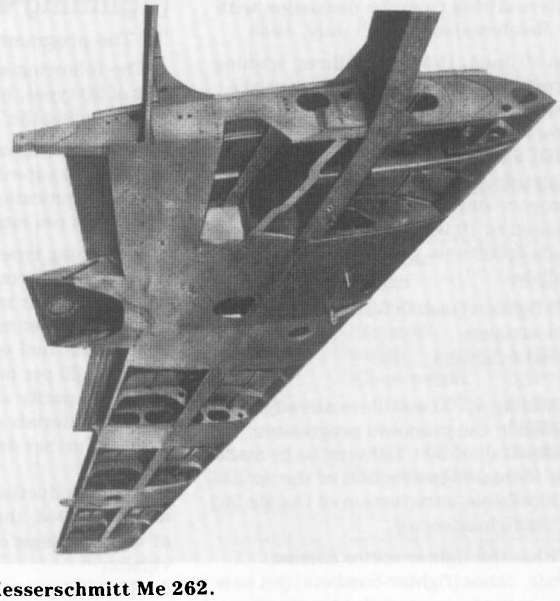
Gradually it became clear that the Me 262's best role was as a fighter. Considering the many technical modifications and degree of outside interference, it is suprising that the 262 managed to emerge as the fastest, most powerful fighter of the second World War. The external form remained virtually unchanged after the V2, and the major structural alterations necessitated by the adoption of the nosewheel undercarriage had been completed by the time the V6 was made.

Technical Description

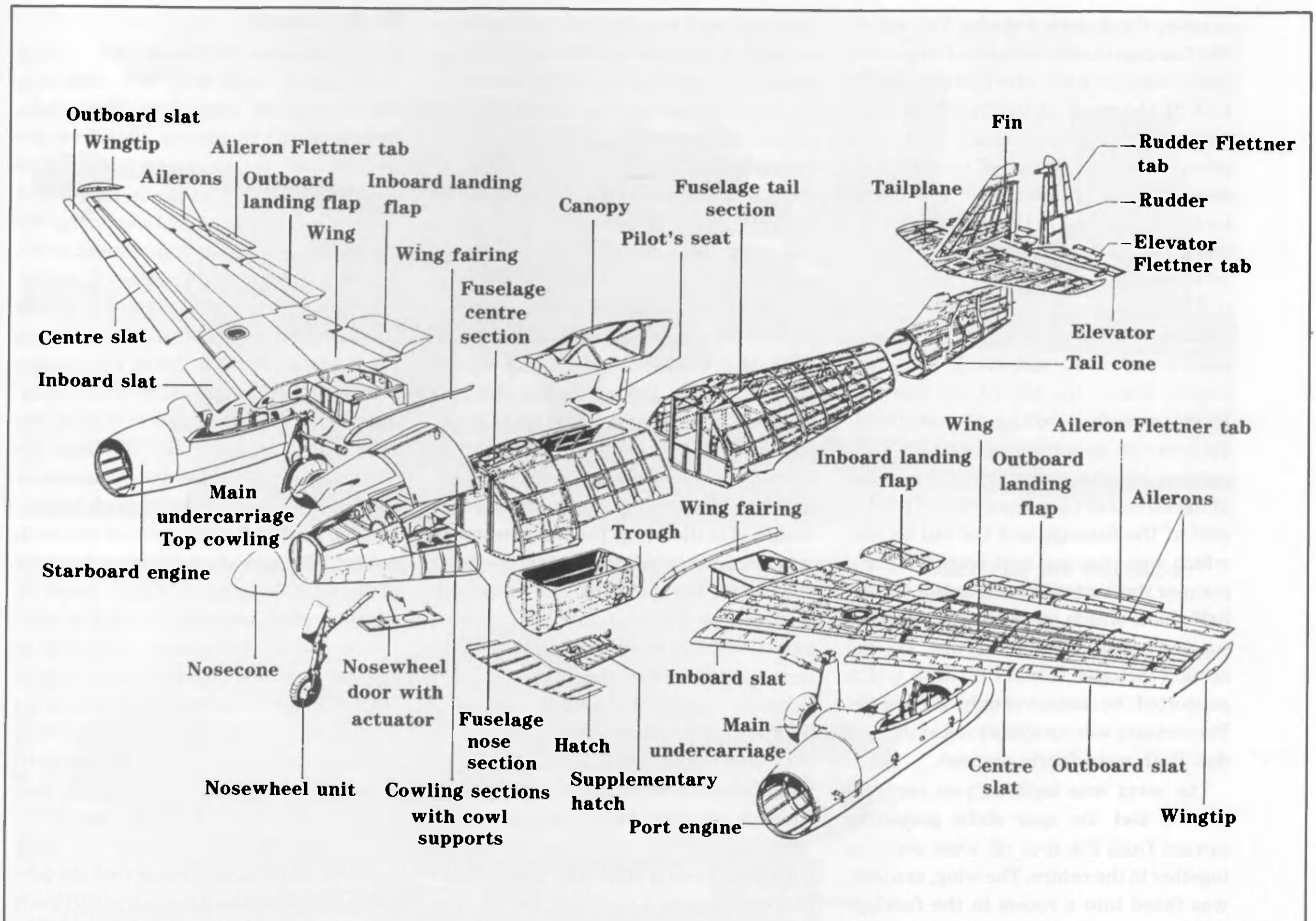
The photographs and the cut-away drawing provide a clear idea of the Me 262's shape and overall construction. The exploded drawing opposite shows how the aircraft consisted of many separately fabricated sub-assemblies, which were brought together for final assembly. The fuselage front section housed the nosewheel and its retracting mechanism, in addition to weapons and ammunition. Four 30 mm MK 108 cannon were installed, firing forward, of which two were supplied with 80 and two with 100 rounds. The firing rate was around 600 shots/



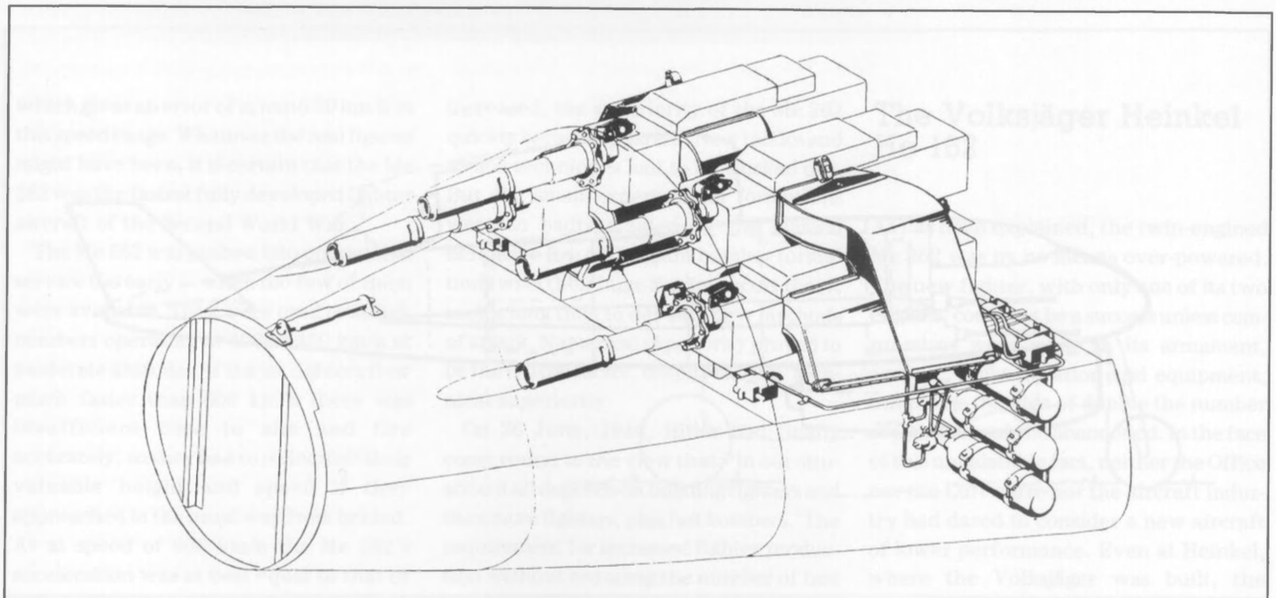
Me 262 as a bomber.



Messerschmitt Me 262. Wing structure, detachable equipment hatches removed.



Exploded drawing of Me 262



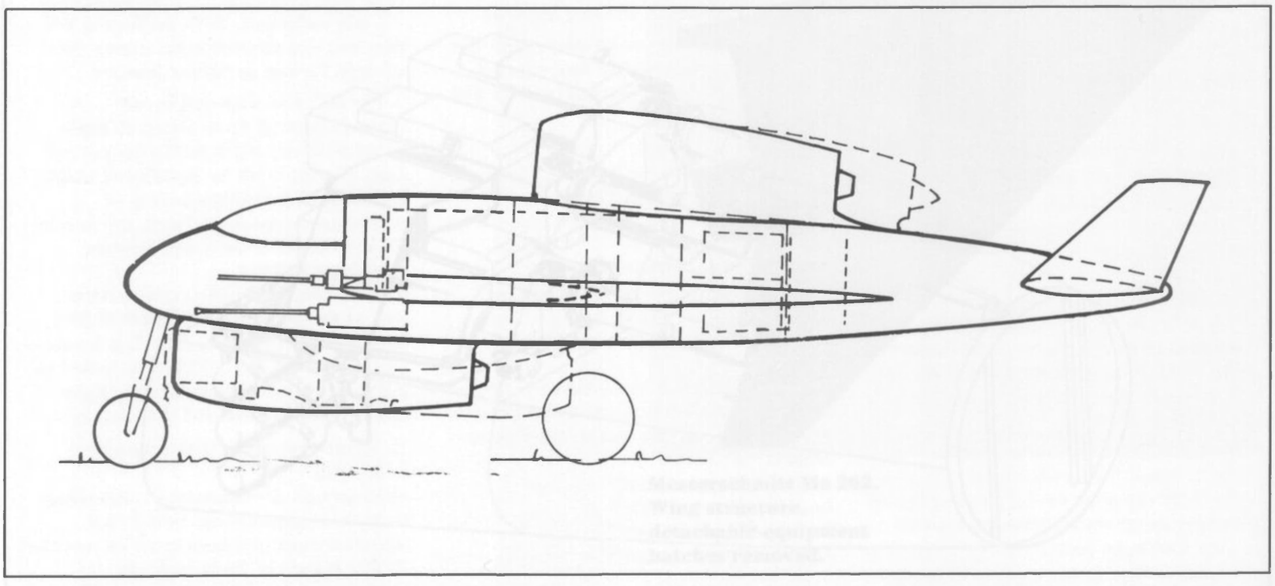
Messerschmitt Me 262. Weapons installation, four 30 mm MK 108 cannon (Rheinmetall-Borsig).

minute, the muzzle velocity 520 m/sec. The fuselage centre section in front of the pilot contained a 900-litre fuel tank which took up the whole of the triangular fuselage cross-section. Immediately behind the pilot, in the rear section of the fuselage, was a further 900-litre tank. A 260-litre tank was situated in the nose of the aircraft. The pilot sat in an open-topped box which was suspended in the upper part of the fuselage centre section. The cockpit glazing, which consisted of Plexiglas panels and a 90 mm thick armoured screen, sealed the top of the box and formed a pressurised high-altitude cabin. This was an important innovation, as it protected the fuselage structure from most of the effects of excess pressure. The rear part of the fuselage and the tail section which was attached to it were built in a manner similar to that of the 109, in two half-shells which were riveted together top and bottom after fitting out. The tail section included a short fin stub which supported the cantilever tailplane and fin. The elevator was cut away to clear the rudder. Both were fabric covered.

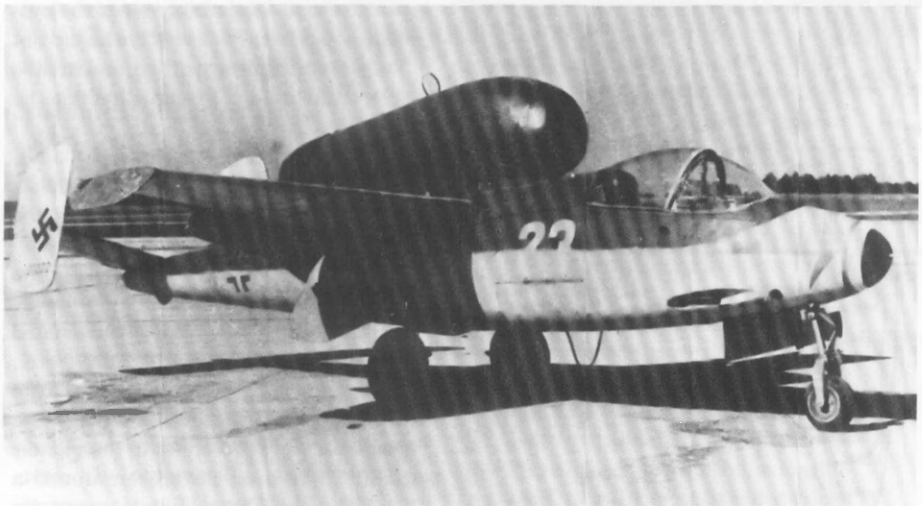
The wing was built as two separate panels, and the spar stubs projecting inward from the root rib were screwed together in the centre. The wing, as a unit, was fitted into a recess in the fuselage centre section. Two fittings on the secondary spar engaged in two corresponding fittings on the main bulkhead in the rear fuselage, and two further fittings on a secondary spar behind the leading-edge slats fitted into corresponding fittings at the bottom corner of the main bulkhead behind the forward 900-litre tank. These fittings were not very strong. The components which actually tranferred the forces between wing and fuselage were two steel ribs, each of which was 'sewn' to a flange on the fuselage side with 20 bolts. The steel ribs were very stout, and were uninterrupted except for the small cut-outs to clear the undercarriage spring struts. When retracted, the wheels were located in the space between the main spar and the rear subspar below the pilot's seat. The entire main undercarriage system, including the retracting mechanism, was mounted in the wing. The wing structure was identical in principle to those of the 109 or 110. The main bending loads were absorbed by a mainspar, this time with steel flanges to save on aluminium. The upper surface of the wing was completely skinned, while the underside featured rigid box areas sealed by ribs, interspersed with several screw-on covers. The inboard wing, between the engine nacelle and the fuselage, was fitted with slats and a landing flap. The outboard wing also carried a divided leading-edge slat, an outboard landing flap and a two-part aileron. The slats were automatic in operation, as on the preceding Messerschmitt fighters and destroyers.

Performance

Our information on the aircraft's flying performance, especially that regarding maximum speed, is highly variable. Flight reports dated 1 September, 1944, from the Rechlin test centre quote a maximum speed of 740 km/h at ground level and 810 km/h at 9,000 m altitude, using the maximum permissible engine speed at the time of 8,700 rpm, and at a take-off weight of 6,100 kg. The rate of climb was stated as 14.7 m/sec at 2,000 m altitude, and 1.3 m/sec at 12,000 m. The test results were based on a large number of spot readings, with little scatter. However six weeks later, on 18 October, 1944, the same aircraft with new engines was measured at 780 km/h at ground level (40 km/h faster), and 820 km/h at 9,000 m altitude (10 km/h faster). The aircraft development record of the GL/C-E Technical Office dated 15 October, 1944, includes the figures mentioned above, which were measured at Rechlin, and a calculated performance curve showing 760 km/h at ground level and 850 km/h between 6,000 and 8,000 m altitude. The corresponding figures calculated by the company, and stated in a performance record dated 12 August were: 805 km/h at ground level and 878 km/h at 6,000 m. The US Navy measured the performance of captured aircraft at 840 km/h maximum level speed at 4,600 m altitude, but it is not known what Mach correction was made for the air-speed indicator,



Heinkel project P 1073 for a twin-engined single-seat fighter, which was intended to achieve high Mach numbers through wing sweepback and staggered engines — the first application of area ruling.



Heinkel He 162 Volksjäger (people's fighter).

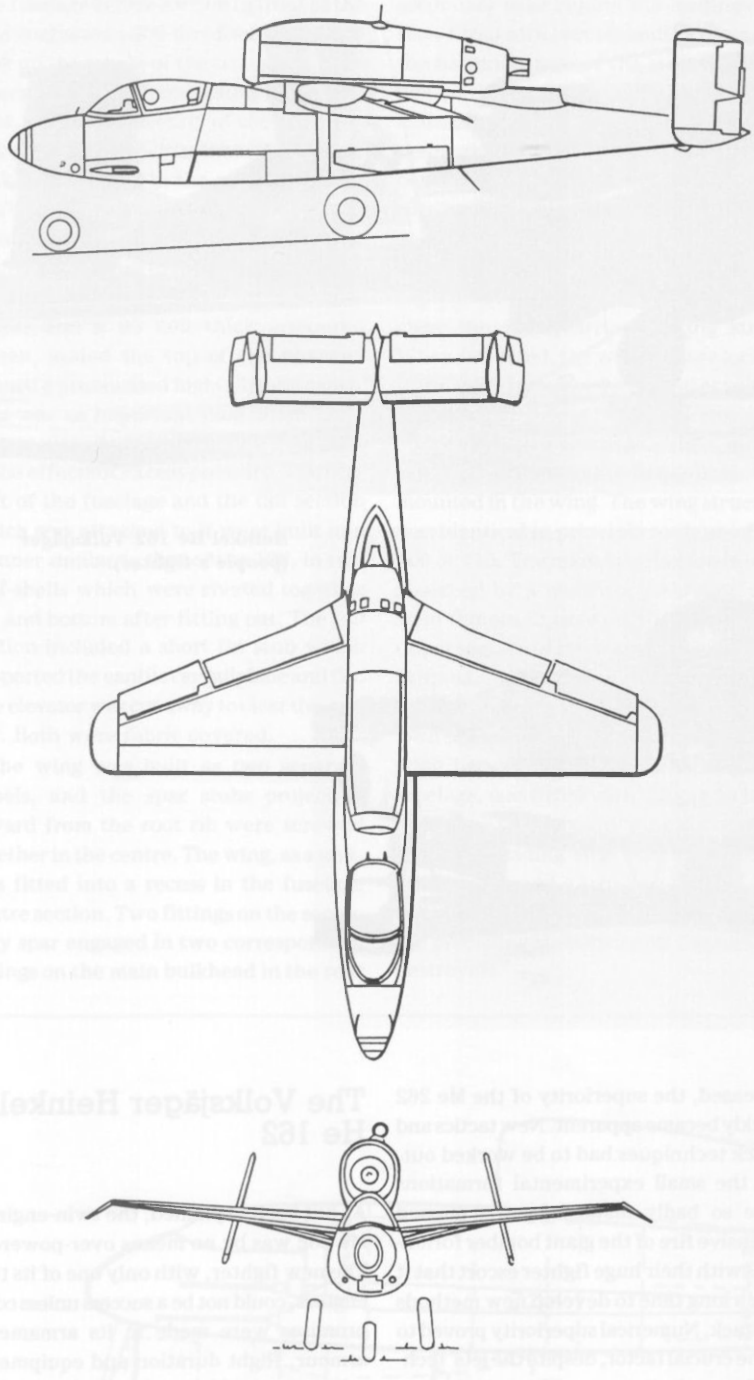
which gives an error of around 50 km/h in this speed range. Whatever the real figures might have been, it is certain that the Me 262 was the fastest fully developed fighter aircraft of the Second World War.

The Me 262 was pushed into operational service too early — when too few of them were available. They were used to attack bombers operating at 400 to 450 km/h at moderate altitudes. If the jet fighters flew much faster than 600 km/h there was insufficient time to aim and fire accurately, so they had to relinquish their valuable height and speed if they approached in the usual way from behind. At at speed of 600 km/h the Me 262's acceleration was at best equal to that of the enemy piston-engined fighters which escorted the bomber formations. At lower speeds the climb rate of the jets was substantially worse than the Spitfires and Mustangs, due in part to the propeller aircraft having lower wing loadings. As speed increased, the superiority of the Me 262 quickly became apparent. New tactics and attack techniques had to be worked out. But the small experimental formations were so badly mauled by the massed defensive fire of the giant bomber formations with their huge fighter escort that it took a long time to develop new methods of attack. Numerical superiority proved to be the crucial factor, despite the jets' technical superiority.

On 26 June, 1944, Hitler had finally come round to the view that: 'in our situation it all depends on building fighters and then more fighters, plus fast bombers.' The requirement for increased fighter production without reducing the number of fast bombers prompted the idea of a smaller, single-engined fighter, which would provide double the number of aircraft from the same rate of engine production. The concept of the Volksjäger — the people's fighter — was born.

The Volksjäger Heinkel He 162

As has been explained, the twin-engined Me 262 was by no means over-powered. The new fighter, with only one of its two engines, could not be a success unless compromises were made in its armament, armour, flight duration and equipment, otherwise the idea of double the number of fighters could be abandoned. In the face of this unpalatable fact, neither the Office nor the Luftwaffe nor the aircraft industry had dared to consider a new aircraft of lower performance. Even at Heinkel, where the Volksjäger was built, the machine was preceded by projects for faster twin-engined single-seat fighters (there was no single engine of higher power). Heinkel's intention was to mount the engines in tandem rather than side by side on the wing, and push up towards



Heinkel He 162 Volksjager

Wingspan	7.2 m
Length	9.05 m
Wing area	11.2 sq m
Empty weight	1,665 kg
All-up weight	2,805 kg
BMW 003	800 kg thrust

Mach 0.9[40] by sweeping back the wing and tail surfaces.

The Volksjager, or He 162, was formed by omitting the front, lower engine and shrinking the aircraft to a size appropriate to the BMW 003 engine; the entire Jumo 004 production being reserved for the Me 262.

Before Heinkel was awarded the official contract, a design competition had to take place. Companies were given no more than two or three days notice of this. One day in mid-September 1944 an expert from the Technical Office arrived unexpectedly at the Arado development department, which had been moved to Landeshut in Schlesien. He required a project for a light fighter powered by the BMW 003 engine, and he required it in a few days. He seemed to know quite accurately what the outcome would be. For two days he did not budge from the design office, and tried to steer the project in the direction he wanted.

The firm was stretched to the limit, working on further development of the Ar 234, as well as on two further types[41], and was quite unable to devote more than minimal time to the task. But after 2½ days the Technical Office expert took away with him a design complete with estimated weights and performance figures, etc., which had a number of similarities to the Heinkel effort. A few days later the proposals were presented to the Fighter Staff. There must have been around a dozen designs, if my memory is correct, for most companies, especially those whose aircraft had been cancelled in the great shake-out of 1 July, had produced more than one design, and were making a final effort to obtain a fighter contract. Some had been revised at the eleventh hour, after the weight and performance figures of other designs had been studied.

In coarse terms the projects presented could be divided into two classes: engine and air inlet either below or above the pilot's seat or fuselage. Anyone who had seen the flames, often metres long, which a jet engine could hurl out when it misfired, was bound to settle for the configuration with the engine above the fuselage.

On the other hand the airflow to the engine at large angles of attack would be disturbed by the front part of the fuselage and the cockpit with this arrangement. If the air intake was located at the fuselage nose, the airflow situation would be very good, but the inlet's close proximity to the ground meant that foreign bodies were

likely to be sucked into the engine, with obvious results. Bearing in mind the airfield conditions to be expected, this was a serious problem. All the designs presented had one fault or another. Six weeks after the Fighter Staff meeting I was given the order to discuss Heinkel's design with the company in Vienna. The same thing had happened in the spring with the Me 262, and once again I was to provide either a clean bill of health or recommend modifications to the design. And that at a time when the essential sub-assemblies were already virtually completed. After two days of strenuous work I set out for home in the early hours of the morning. The shop windows and shop doors in the Kartner Strasse were covered with hectographed posters calling for defection from the Third Reich. It was All Souls day, 1944. Five weeks later, the He 162 was flying.

Technical Description

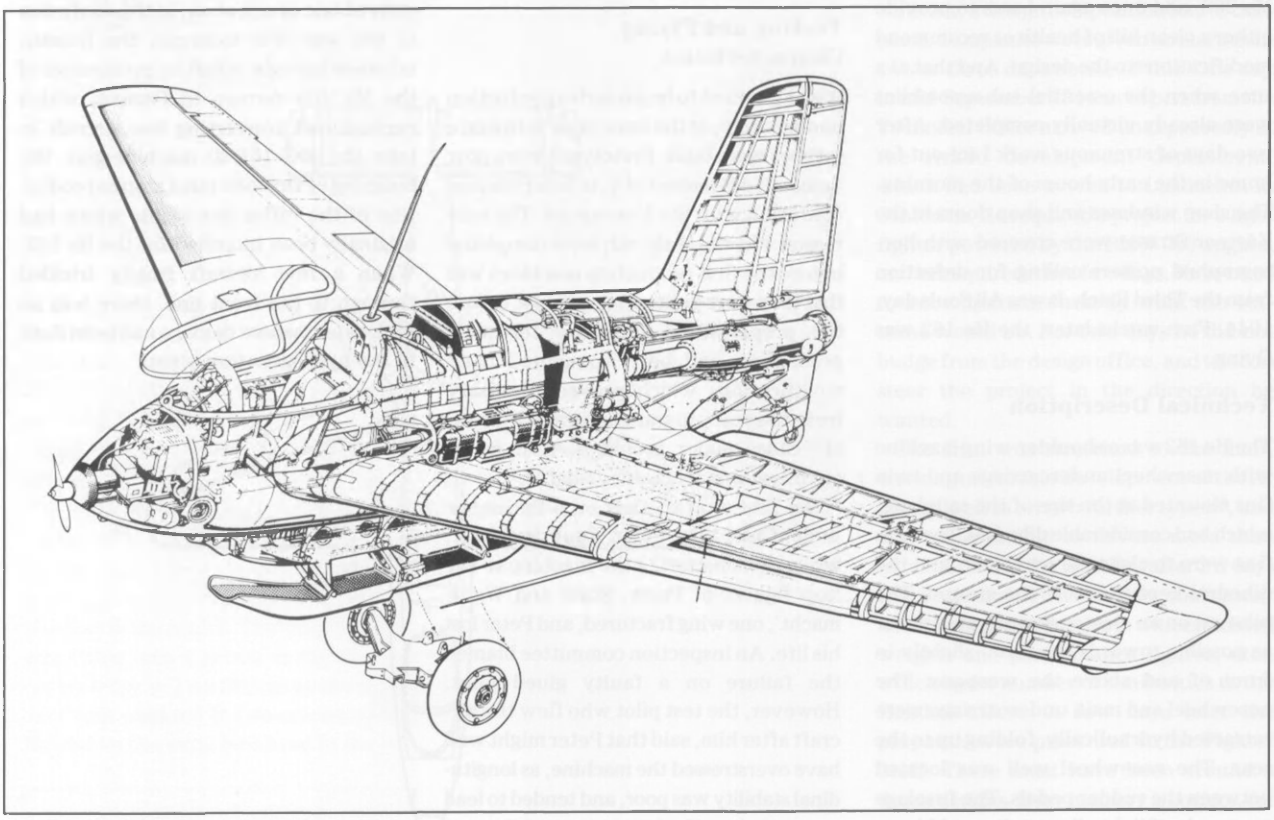
The He 162 was a shoulder-wing machine with nosewheel undercarriage and twin fins mounted at the tips of the tailplane, which had considerable dihedral. The twin fins were to clear the jet efflux, and the dihedral kept them off the ground. The pilot sat on an ejector seat situated as far as possible towards the nose, slightly in front of and above the weapons. The nosewheel and main undercarriage were retracted hydraulically, folding up to the rear. The nosewheel well was located between the rudder pedals. The fuselage was made of light alloy, as it would have been too complicated to install attachments for the undercarriage, engine, wing, tail and fittings such as weapons, ammunition boxes, seat, control system, etc. in a wooden structure. The wing, including ailerons and landing flaps, was made entirely of wood, as were the fins and most of the fuselage-mounted doors which closed the undercarriage wells, etc. The tailplane was built in light alloy, to ensure adequate rigidity. The one-piece wing had a T-section mainspar, which was located at the quarter-chord point at the root, and at the mid-chord point at the wingtip. There was also a secondary spar at roughly two-thirds of the wing chord. The spar flanges were made in T-Bu, a material consisting of beech-wood plates pressed together with Bakelite. In other respects the wing was constructed by the standard techniques in use since long before the war, *e.g.* on the He 70. Full ribs were used, and the wings were entirely skinned with plywood. The space between the spars in the inboard third of the wing was impregnated with fuel-proof material and served as fuel tank, feeding the fuselage tank by gravity. The leading edge was perfectly straight. Two 30 mm Mk 108 cannon were planned as armament, with 50 rounds each. The only armour protected the pilot from the straight-ahead direction.

Testing and Flying Characteristics

It was planned to begin series production immediately, at the same time as the prototypes were built. Prototypes were now designated M instead of V, in order to avoid confusion with the V-weapons. The only reason why the M aircraft were completed before the first production machines was that they were built as one-offs, *i.e.* before the preparations necessary for mass production had been completed. Any modifications which proved necessary from the test programme would inevitably cause major problems. And major modifications were unavoidable.

The first aircraft flew on 6 December under Chief Pilot Peter. Four days later, while demonstrating the machine to the 'top figures of Party, State and Wehrmacht', one wing fractured, and Peter lost his life. An inspection committee blamed the failure on a faulty glued joint. However, the test pilot who flew the aircraft after him, said that Peter might well have overstressed the machine, as longitudinal stability was poor, and tended to lead to coupled oscillations between pilot and aircraft at high speed. The dihedral tailplane was on the small side, and was largely blanketed by the wing, especially at small angles of attack. After much experimenting, the problem was overcome by increasing the tailplane span and raising the wing incidence angle by 2 degrees, thereby deflecting the airflow downward, away from the tail. Stability around the vertical axis was also inadequate. The wing dihedral was excessive for a high-wing configuration, and this, coupled with tail dihedral resulted in a tendency to Dutch roll. The solution here was to enlarge the fins. The effects of the excessive wing dihedral were alleviated by fitting downward-canted wingtips. A turbulator strip was glued to the wing leading edge to combat an initial tendency to tip-stall. When all the modifications had been made, the He 162 proved to be a pleasant aircraft for the experienced pilot, but difficult for the average pilot, especially on landing. An experienced British test pilot, who flew the He 162 on many occasions after the war, classed it as 'delightful' to fly: an aircraft with quite outstanding directional stability, making it the best gun platform he had ever flown.

The protracted testing delayed the machine's operational service, but this was not the only reason. Spare parts arrived late or not at all, in the confusion of the war. For example, the Russian advance brought a halt to production of the Mk 108 cannon in Poznan, which necessitated converting the aircraft to take the MG 151/20 machine-gun; the bombing of Dresden put a stop to production of the reflex gun sights which had originally been intended for the He 162. When a few aircraft finally trickled through to the front line, there was no fuel, as permanent damage had been done to the hydrogenation plants.



Messerschmitt Me 163 structure.

The Rocket-propelled aircraft

The Messerschmitt (Lippisch) M3 163

The constantly increasing intensity of air attacks on industrial sites after mid-1943 had resulted in companies being dismantled and production distributed over the entire country. Many industrial installations, *e.g.* the hydrogenation works or blast furnaces, could not be moved. Massed bomb attacks were directed against these sites, and their destruction had a profound effect on the entire defensive capability of the country. For example Leuna and Poelitsch, the main hydrogenation works in the Central German brown coal region, were subjected to attack by 1,000 bombers with an escort of 700 fighters. The precise target of these attacks usually only became apparent at the last minute, and it was often half an hour or more before some sort of defensive cover could be brought to bear from the depleted ranks of the Luftwaffe, and by then the damage was done. This situation led to the concept of a special fighter — 'object guard' — which was to be posted close to the object, or target. This fighter was to be small, light and cheap, have a superior climb and speed performance, have no delaying effect on the emergency fighter production programme and be available at the target area in large quantities within a few minutes of the start of an attack. The specification of the new machine described a single-seat rocket-propelled aircraft with two 30 mm MK 108 cannon or other suitable weapons.

The Me 163, which had originally been designed for other tasks, already existed, and appeared suited to the new situation. In the course of further development on the Me 163 it became clear that the task of the 'object guard' could be fulfilled more efficiently with a smaller, less complex aircraft, and for this reason the emergency fighter programme included a new specification for the rocket-powered single-seat fighter. However, nothing better came out of it.

The origins of the Me 163 lay in a series of tailless aircraft which had been built by Alexander Lippisch in the workshops of the Rhon-Rossitten Company, later to become the German Research Institute for Gliding Flight, the DFS. The work was promoted by the research division of the Air Ministry, LC-1, as it was believed that higher performance aircraft could ultimately be achieved with the tailless configuration. The idea that the layout would be particularly suitable for rocket propulsion must also have played a part. The DFS, *i.e.* Lippisch, was granted a contract to build a tailless aircraft with rocket propulsion. Lippisch took his team and his project to Messerschmitt, where work continued on the machine, under its new designation of Me 163, and now under the wing of the development division of the Technical Office LC-2.

Technical Description

In its outward appearance the Me 163 was an unusually simple, elegant mid-wing aircraft. The wing, with its aspect ratio of around 4.5:1, was swept back by 23.5 degrees. Stabilisation around the yaw axis was provided by a large, central fin. The relatively small landing flaps were used more to control the glide angle than to increase lift. The ailerons took up around 40 per cent of the semi-span. Deflected in the same direction, they worked as elevators; in opposite directions, as ailerons. From the wingtip inward fixed leading-edge slots extended over 55 per cent of the semi-span, guarding against airflow breakaway at the stall. According to its pilots, the Me 163 was an extremely pleasant and safe aircraft, which could not be provoked into dropping a wing or spinning, no matter what the piloting error.

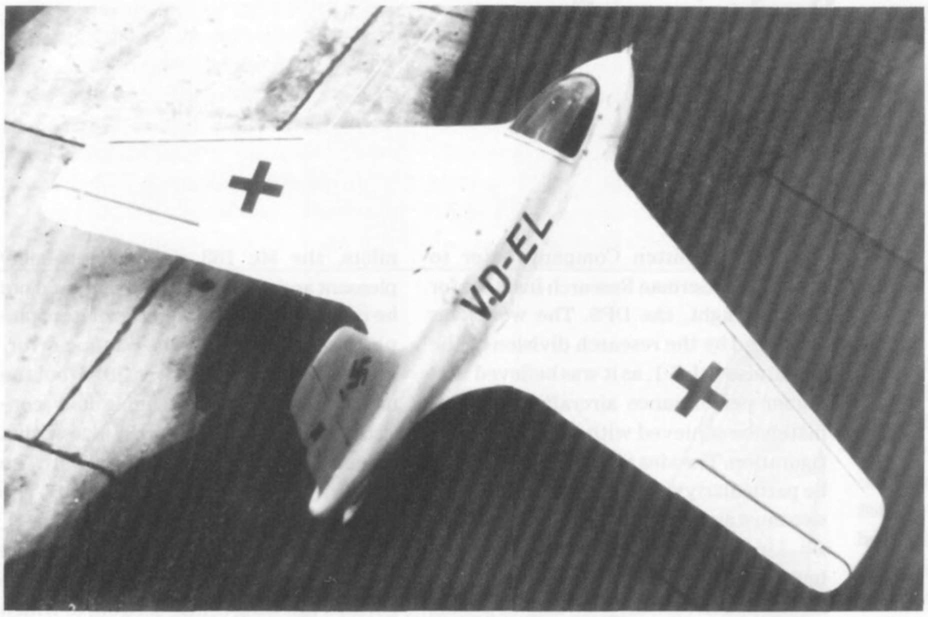
A central landing skid was fitted, but the machine took off from a simple dolly, consisting of little more than an axle with a wheel at each end, under the skid. The dolly was jettisoned soon after lift-off. The aircraft also had a retractable tailwheel, for manoeuvrability on the ground. The fuselage was built of light alloy, and incorporated the wing centre section, to which the outward wing panels were attached. The wing was made of wood, as was the fin, and was a spar and rib structure skinned with plywood. The whole wing was covered with fabric. The inboard part of the wing housed fuel tanks fore and aft of the mainspar, which was located at the quarter-chord point. The main tanks, along with the rocket engine, were in the fuselage.

The Me 163 Power Plant

It is not strictly correct to use the term 'fuel' in relation to the early engines, as there was no burning, no oxidation; in fact, quite the contrary. The propellant, a high-percentage hydrogen peroxide, decomposed in a reaction chamber on contact with a catalyst (potassium permangenate), forming water and oxygen. Two parts peroxide decomposed into two parts water and one part oxygen. The process released heat, which turned the water into hot

Specification, Me 163B-1

Wingspan	9.35 m
Length	5.85 m
Wing area	18.5 sq m
Engine	HWK 509A-2
Thrust	16.6 kN (1,700 kg)
Armament	Two MK 108 cannon, 60 rounds each
or	Two MG 151/20 machine-guns, 100 rounds each
Airframe weight	1,910 kg
All-up weight	4,315 kg
Duration at full power	7.5 min (overall)
	2.5 min (after initial climb)
Rate of climb	80 m/sec
Maximum speed	960 km/h



Messerschmitt Me 163 (without engine).

steam, which escaped through the rocket nozzle at high speed and thus produced thrust.' It was, in fact, a steam rocket. If the oxygen produced could be harnessed to burn a hydrocarbon, then the temperature could be increased markedly, with a resultant increase in thrust — or a corresponding decrease in specific consumption. This refinement was planned, but unfortunately the propellants were not all that easy to handle, and it was a long time before the combustion engine could be permitted for flight operations.

The first test aircraft, DFS 194, was begun at DFS and fitted with an engine rated at 400 kg thrust, built by the firm of Walter at Kiel. However, the engine's high specific consumption only allowed very short flights. The next engine, rated at 750 kg thrust, had the same high specific consumption. The take-off and climb out consumed so much fuel that there was not enough left to accelerate the aircraft to high speed. However, after an aero-tow, the pilot Heini Dittmar, who had made all the test flights of the tailless aircraft for many years, reached and exceeded 1,000 km/h and also the Mach limit of the aircraft dictated by the rocket thrust of 750 kg. At this Mach number, around 0.85, the machine became completely uncontrollable, but it recovered when the engine throttled back.

A speed of 1,000 km/h was a spectacular achievement and earned a special prize, and it is interesting to compare the Me 163 with the piston-engined fighters of the period: to obtain a thrust of 750 kg at 1,000 km/h using an airscrew would have required an output power at the shaft of 3,500 hp, assuming that 80 per cent propeller efficiency would still have been available at this speed. The fuel consumption of the Walter rocket engine was 4.35 kg/hp/h, or roughly twenty times the calculated figure for a piston engine of similar output. The fuel consumption was eight and a half times greater than that of the Jumo 004 turbojet. In spite of the Me 163's impressive performance it was clear that it had no military application unless a major increase in thrust and a reduction in fuel consumption could be achieved.

Further Development of the Me 163

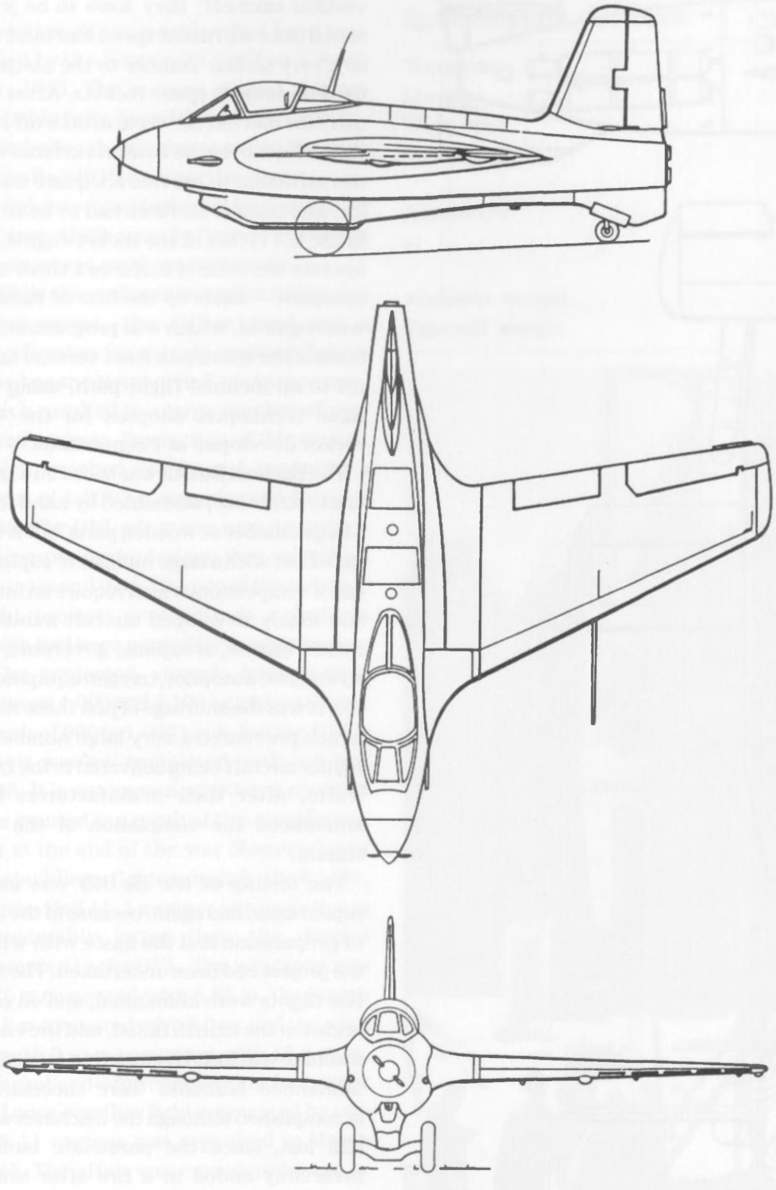
Of the first aircraft, the Me 163A, only 13 test machines were built, but a slightly modified version, the Me 163B, was built for the new, larger engine. Work on the design began in October 1941, and by the summer of 1942 the VI was completed. Very soon a large number of test aircraft were ready, but for a whole year the Me 163B was minus its engine, and had to be tested as a glider after an aero-tow. The first HWK 109-509A engine, producing a thrust of around 1,700 kg, was installed in July 1943. Testing was due to be done at Peenemünde, the rocket testing station on the island of Usedom, but the installations there were destroyed by air attacks, and the facility was moved to Bad Zwischenahn in Ostfriesland, where a training group was already working with 163A machines. The fact that rocket fuels were not exactly straightforward to handle was proved again and again in a long series of accidents. But even on normal landings the aircraft were often damaged, as, in a sense, every flight ended in an emergency landing. An accident on landing very often led to an explosion and severe damage, as the two fuel components reacted spontaneously when they came into contact. The number of losses was very high, and soon there were none of the zero-series aircraft left.

The first aircraft of the Me 163B-la series, which was equipped with two 30 mm MK 108 cannon with 60 rounds each,

Me 163C

Wingspan	9.8 m
Length	7.05 m
Wing area	20.4 sq m
Thrust	16.6 + 2.9 kN (1,700 + 300 kg)
Airframe weight	2,200 kg
All-up weight	5,300 kg
Duration at full power	12 min (overall) 6.5 min (after initial climb)

Messerschmitt 163B, the version of which most were built.



Messerschmitt Me 163

arrived at Lechfeld for test flying at the end of February 1944. In May the Luftwaffe received its first aircraft. In June the number supplied was three, in July twelve. In July the first operational squadron was stationed at Brandis near Leipzig to guard the hydrogenation works, as was the second squadron. The aircraft's first operational flight took place on 28 July, 1944. The total number of Me 163Bs supplied during 1944 was said to be 237 units, but in 1945 it was only 42.

The operational success of the Me163B was anything but spectacular, due to the high flying speeds. It suffered from the same problem as the Me 262, but to an even greater extent. The specific fuel consumption remained high, especially when the engine was throttled back, and a second, smaller combustion chamber providing 300 kg thrust was added in an attempt to overcome this problem. The fuel supply was also increased, and the extra weight and machinery called for a larger airframe; the result was the Me 163C. Junkers designed a new version with a longer, slimmer fuselage and a normal, retractable nosewheel undercarriage. This was the Me 163D, known as the Ju 248 at Junkers. Neither the C nor the D variants was produced in series.

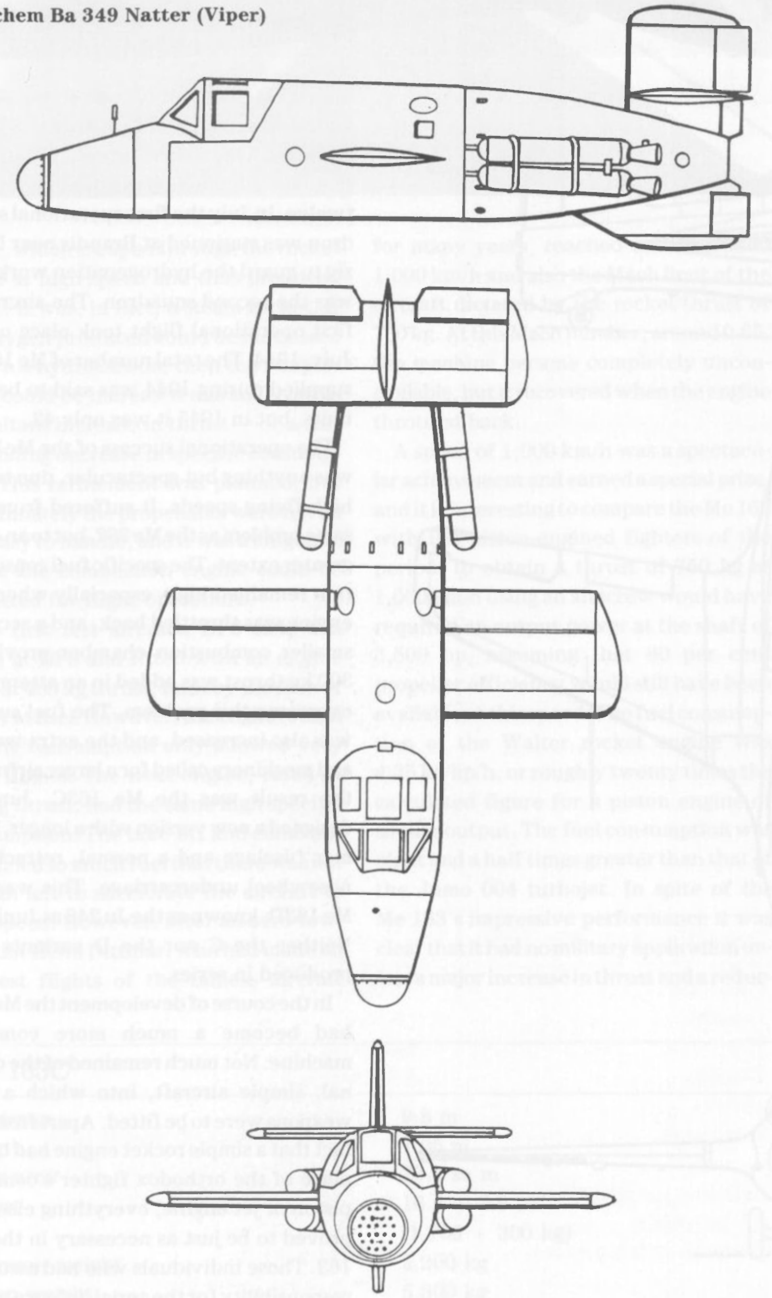
In the course of development the Me 163 had become a much more complex machine. Not much remained of the original, simple aircraft, into which a few weapons were to be fitted. Apart from the fact that a simple rocket engine had taken place of the orthodox fighter's complex piston or jet engine, everything else had proved to be just as necessary in the Me 163. Those individuals who had assumed responsibility for the aerial defence of the Reich at the eleventh hour had harboured a dream of a cheap, practical 'object guard'

which could be produced in very large numbers, but the idea had to be brought to life in a different form. Under the aegis of the SS, Erich Bachem, who had worked at the Fieseler factory in Cassel until the summer of 1944, designed and built a cheap, rocket-propelled aircraft in his own workshops at Bad Waldsee; it was what we would call today a non-returnable flying machine.

The Bachem Ba 349 Natter (Viper)

The idea which led to this primitive aircraft, known under the name Natter (Viper), was to produce a vertical take-off, rocket-propelled flying machine, armed with rockets, which could return to earth on a parachute after carrying out an attack. At a stroke this would solve the aircraft problem, the airfield problem and also the pilot problem. The pilot only needed the ability to direct his machine at the target at high speed, in order to release a salvo of rockets when the range was right. It was also planned to fit two MK 108 cannon with 30 rounds each, either in addition to or instead of the rockets. After the attack the fuselage front section would be jettisoned, the aircraft's parachute would open, and the pilot would bale out on his own chute.

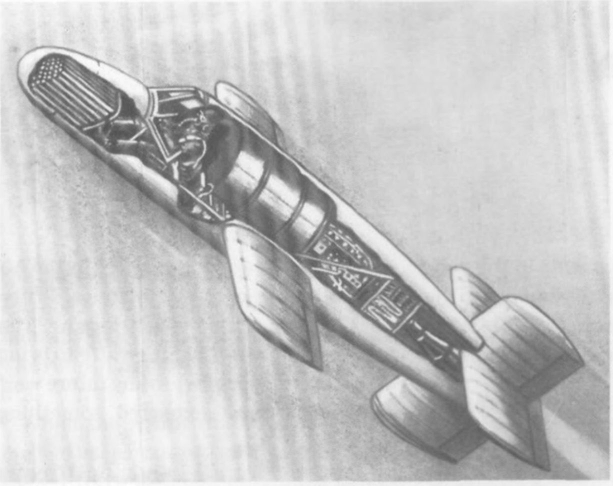
Bachem Ba 349 Natter (Viper)



These plans left many questions unanswered, but they resulted in a machine whose total weight was greater than the thrust of the drive rocket — the Walter HWK 509A-2 engine, which was the unit used in the Me 163. Auxiliary powder-burning rockets had to be attached to allow vertical take-off; they were to be jettisoned once sufficient speed had built up, in a very similar manner to the methods used on today's space rockets. After the machine had left the vertical take-off rails the airflow over the control surfaces was not sufficient to provide adequate stability, and control surfaces had to be fitted in the hot efflux of the rocket engine. To operate the control surfaces a three-axis autopilot — made by the firm of Patin — was required, which was programmed to control the transition from vertical take-off to an inclined flight path, using the same techniques adopted for the V 2 rocket developed at Peenemünde.

The Bachem Ba 349 was based on a truly crude structure, assembled by hand from a large number of wooden parts, but it was fitted out with a large number of sophisticated components which require an intact and highly developed aircraft industry: rocket engine, weapons, governors, instruments, autopilot, oxygen equipment, etc. It was the shortage of just these items which prevented a very large number of fighter aircraft being delivered to the Luftwaffe, after their manufacturers had announced the completion of the airframes.

The testing of the Ba 349 was interrupted again and again, because of the lack of preparation and the haste with which the project had been undertaken. The first test flights were unmanned, and on each occasion the launch failed, and the entire machine was lost. Eventually a number of unmanned launches were successfully accomplished although the machines were still lost, since the parachute landing invariably ended in a fire after touchdown. A manned flight ended in a crash and the death of the pilot. Work continued on the Natter until enemy troops arrived,



Bachem Ba 340 Natter.

even though the machine had been cancelled by the Armament Staff on 5 January, 1945. The reasons behind this are probably to be found deep in the psychosis linked to the imminent end of the war.

The Ba 349 Natter was the last interceptor fighter project intended for German air defence which actually flew, even though it was never used operationally.

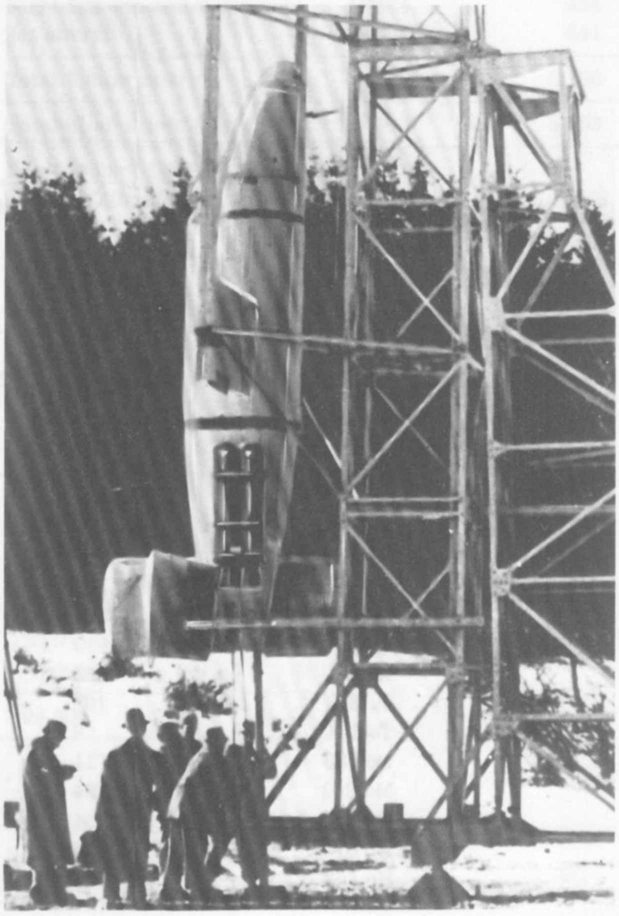
While this rocket interceptor was under development, the Office produced a specification for a single-engined fighter based on the Heinkel HeS 11-A jet engine, which resulted in a large number of proposed projects. Production of this engine, which weighed 845 kg and produced a thrust of 1,300 kg, was planned for mid-1945. The DVL adopted a new procedure for comparing the designs; they calculated the mass and performance of the seven or eight projects according to a formula which had been agreed by the companies.

The projected aircraft had weights between 4,000 and 4,100 kg and maximum speeds of 960 to 1,000 km/h, but the DVL's report was not completed until January 1945. It is not known whether a contract was granted as a result of this completion, but at the end of the war Messerschmitt was building a fighter aircraft, the P 1101, for the HeS 11-A engine, although it was considerably larger than the designs presented to the DVL. The wingspan was 8.25 m compared with 6.65 m, the length 9.18 m compared with 8.0 m, and the wing area 15.9 sq m compared with 12.6 sq m.

A similar design competition for a night and poor-weather fighter powered by two HeS 11 engines was organised in March 1945. The affair was considered more or less seriously by the manufacturers, depending on whether their factories had been rolled flat by the Front or not.

Specification, Ba 349B

Wingspan	4.00 m
Length	6.02 m
Wing area	4.7 sq m
Thrust	16.6 kN (1,700 kg) + 4 × 12 kN (1,250 kg) launch rockets
Armament	24 × 72-mm rockets
or	two 30 mm MK 109 cannon (30 rounds each)
Airframe weight	960 kg
Take-off weight	2,270 kg



Bachem Ba 349 Natter on the launch tower.

Strength and Losses of the Luftwaffe: numbers and data

Our description of the development and production of fighter aircraft and destroyers in the 1939-1945 War cannot be considered complete without statistical data, which is an important aid to understanding many of the events in the war.

The quantities of aircraft supplied to the German Armed Forces in the 1914-1918 and 1939-1945 Wars run in parallel to some extent:

Aircraft production during the First World War	
1914	1,348 aircraft
1915	4,532 ,,
1916	8,182 ,,
1917	19,746 ,,
1918	14,123 ,,

Aircraft received by the Luftwaffe during the Second World War	
1939	2,125 aircraft
1940	7,809 ,,
1941	8,869 ,,
1942	13,271 ,,
1943	23,683 ,,
1944	36,953 ,,
1945	6,696 ,,

According to a directive issued by the Air Command Office to the Technical Office on 17 April, 1936, which began: 'The necessity of using the Luftwaffe to bring about a decisive victory in any future war' one might have expected something different.

Fighter aircraft and destroyers accounted for about one third of the total number in the first two or three years of the war. In September 1941 Jeschonnek was chief of the Luftwaffe General Staff. When Milch offered him an increase in production of 720 fighters, he asked what he was supposed to do with so many fighters. But on 25 July, 1942, the head of

Proportion of fighters in overall aircraft production

1939 (September-December)	24%
1940	27.5%
1941	30.2%
1942	34.7%
1943	40.8%
1944	61.7%
1945	77.8%

	Overall strength	Fighters and destroyers strength	Fighters and destroyers proportion
10 May 1940	5,196	1,710	33%
3 January 1942	6,389	1,935	30%

Fighters and destroyers of the German Luftwaffe, 1939-45

	New aircraft	Received by the Luftwaffe	%
Bf 109	30,573	28,103	91.9
Fw 190	20,001	18,010	90.0
Ta 152	67	39	58.2
Bf 110	5,762	5,250	91.1
Me 210	352	259	73.6
Me 410	1,013	892	88.1
He 219	268	195	72.8
Ju 388	103	23	
Ta 154	8	1	
Do 335	11	11	
Me 262	1,294	809	62.5
Me 163	364	225	61.8
Ar 234	214	196	91.6
He 162	116	40	24.7

the Luftwaffe General Staff called for a total of 3,600 aircraft at the Front, and a monthly day-fighter supply of 900 units. The ratio of fighters to bombers was to be 3:2.

When the Army and Luftwaffe were pushed back into defensive positions, the fighter force assumed increasing importance. This is clearly reflected in the production figures, especially for the period between March 1944 and March 1945.

Of the aircraft built less than 90 per cent actually reached the Luftwaffe. Ten per cent were lost by bomb attack at the parking sites, during test flying and during shipment to the Luftwaffe. In spite of considerable efforts to improve the situation, the number of losses always remained similar to the number of new aircraft delivered. The proportion of aircraft which were lost by accident, rather than by enemy action was almost 50 per cent; an extraordinarily high figure. Eighty per cent of all aircraft were lost during the War, which means that 40 per cent of the aircraft supplied to the Luftwaffe were lost without the enemy lifting a finger. In 1945 the figure was 50 per cent.

Production March-December 1944

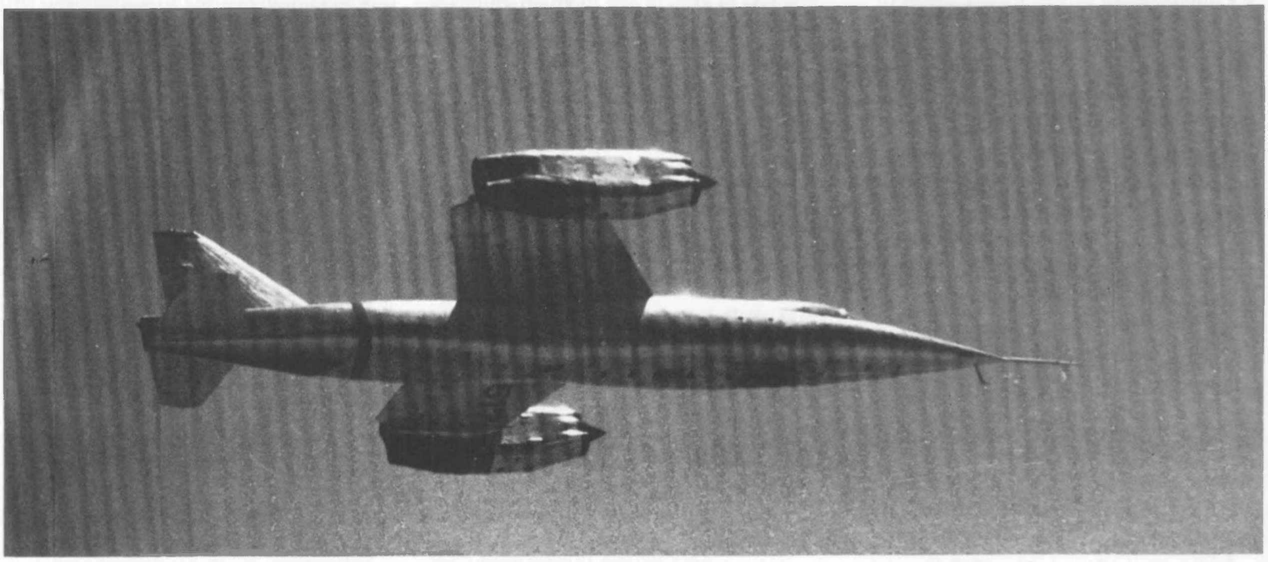
	New machines	Received by the Luftwaffe	%
Day fighters	15,389	12,982	90.9
Night-fighters	3,886	3,492	89.9
Destroyers	657	589	89.6
Jet aircraft	1,041	638	61.3
Total Fighter aircraft types	20,973	18,701	89.2
Total all Front aircraft	30,105	26,570	88.3
Proportion of fighters in total of Front aircraft	69.7%	70.4%	

January-March 1945

	New machines	Received by the Luftwaffe	%
Day fighters	4,461	4,080	91.5
Night-fighters and destroyers	474	434	91.6
Jet aircraft	947	644	68.0
Total fighter aircraft	5,882	5,158	87.7
Total of all Front aircraft	7,213	6,363	88.2
Proportion of fighters in total of Front aircraft	81.5%	81.1%	

Luftwaffe losses, 1939-45

Year	Total losses: Overall	Without enemy influence	%	Aircraft received by the Luftwaffe	Overall loss in %	% loss without enemy influence
1939	835	490	58.7	2,125	39.3	23.0
1940	5,859	2,664	45.5	7,809	75.0	34.1
1941	7,033	3,551	50.5	8,869	79.3	40.0
1942	9,602	4,954	51.6	13,271	72.4	37.3
1943	19,511	10,358	53.1	23,683	82.4	43.7
1944	19,553	13,310	68.1	36,953	52.9	36.0
1945	7,016	3,340	47.6	6,696	104.8	49.9
	79,405	38,667	48.7	99,406	79.8	38.9



VJ 101 built by the Süd development combine. Pursuit fighter for vertical take-off and landing, here in normal forward flight.

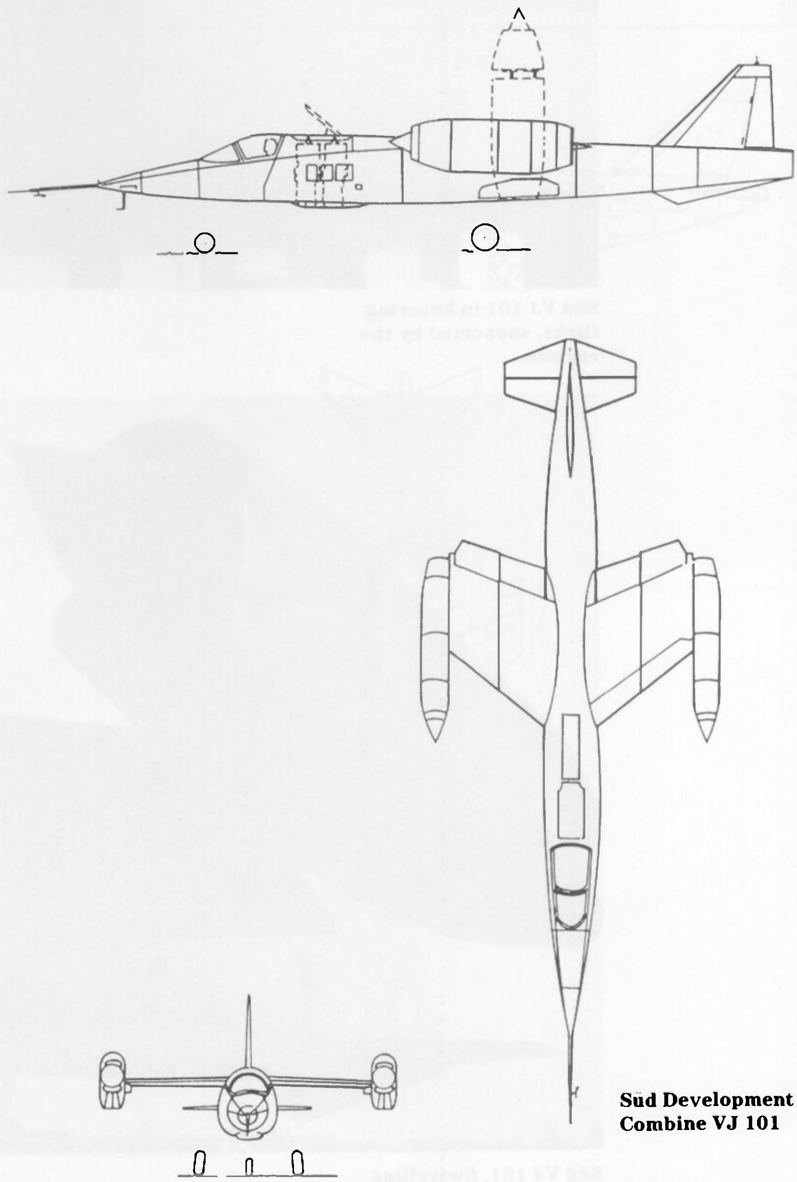
Postwar Fighter Development in the Federal Republic of Germany

Exactly ten years after Germany's capitulation, the Paris treaties on the sovereignty of the Federal Republic and its defence contribution to the North Atlantic pact were ratified. The aviation industry began to re-form, and started by acquiring the rights to build the American Lockheed F-104 supersonic fighter as the first aircraft for the newly created Luftwaffe. The next step was to begin developing an aircraft specially suited for the fighter defence of the West German region.

One important lesson learned in the last war had been the vulnerability of airfields and of the aircraft necessarily parked on or close to them. This was the reason for concentrating on a machine which could take off and land in a very small space, or vertically. These aircraft would thus require no airfields as such, and could be distributed geographically for storage, away from the actual flight-support stations. All round the world VTOL (Vertical Take Off and Landing) was the catchword in military aviation circles. Süd Development Combine, which had won the development contract, set itself a formidable task in designing and building the new aircraft. It was to be able to take-off and land vertically, be capable of supersonic flight, to be able to land safely after an engine failure, and moreover be as small and cheap as possible. A great many designs were studied — this was, after all, completely new territory — before they settled on the VJ 101.

The VJ 101 of the Süd Development Combine

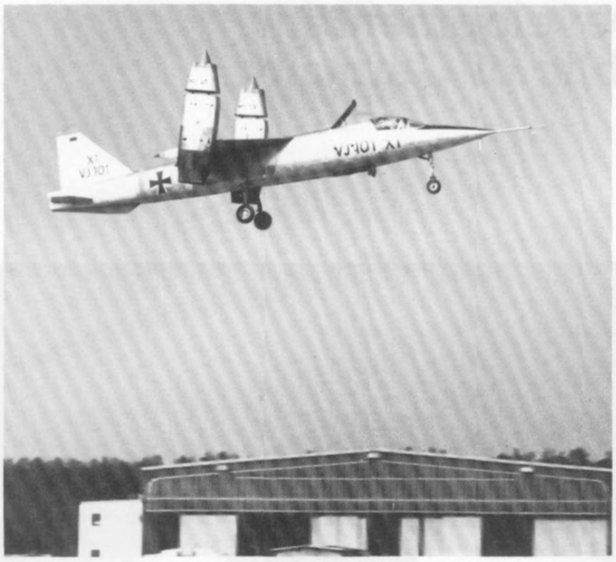
The VJ 101 was a shoulder-wing aircraft with three groups of engines, each consisting of two turbojets; one mounted vertically in the fuselage forward of the aircraft's centre of gravity, and only used for take-off and landing. The other two groups were located at the wingtips, aft of the centre of gravity; these could rotate through 90 degrees around the roll axis. In their horizontal position they provided



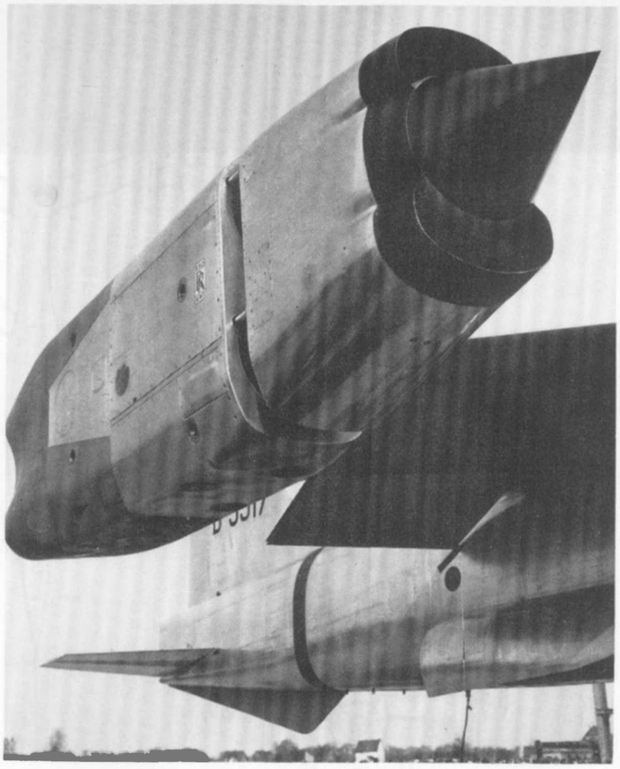
Süd Development Combine VJ 101

Specification of VJ 101 X-2

Wingspan	6.6 m
Length	15.5 m
Wing area	19.0 sq m
Engines	Rolls-Royce RB.145
Thrust (vertical)	2 × 12.3 kN (1,205 kg)
Thrust (cruise)	4 × 15.8 kN (1,610 kg)
Airframe weight	5,450 kg
Take-off weight	7,690 kg



Süd VJ 101 in hovering flight, supported by the engines.



Süd VJ 101. Swivelling engine installation with the supplementary air inlet slot for take-off, landing and hovering.

the forward propulsion in normal flight, with the wings providing lift. For vertical take-off or landing they were rotated to the vertical position. In this mode the machine could be likened to a tripod. The wingtip engines were equipped with afterburners, in order to ensure supersonic capability. The undercarriage was relatively tall, to ensure that the engines did not get too close to the ground when vertical. The mainwheels retracted rearwards into the fuselage, as did the nosewheel. This configuration of engines and undercarriage was selected to allow weapons such as rockets to be attached under the fuselage. The pilot's control system was quite normal, with control column and rudder pedals, which were connected to ailerons, rudder and elevators even when the aircraft was hovering, although their effect gradually fell to zero as speed decreased. In the hover, the aircraft was controlled by the engines. Roll movements were achieved by varying the thrust of the wingtip engines, yaw by tilting them slightly in opposite directions out of the vertical, pitch by raising or lowering the thrust of the forward engines. When hovering, the aircraft was able to move sideways, by tilting it in the desired direction, or forwards and back by inclining it forward and aft. A governor stabilised the aircraft in all situations, although the pilot could override the regulator at any time. The transition from hovering flight to forward flight, with the wings lifting, was accomplished by altering the inclination of the engines. With increasing speed the influence of the engines on control became smaller, falling to zero in the horizontal position.

The VJ 101 incorporated two notable innovations. One was the engine's fast response to thrust variation commands, which allowed them to be included in the control system along with engine inclination. The second was the flight governor, which was able to maintain the aircraft's position, and also its height above ground in hovering flight, completely automatically.

The air intake and outlet of the front (vertical thrust) engines were covered by flaps when the wings were providing lift. The flap over the inlet directed the air round the engines in an axial direction as flying speed increased. To ensure adequate inlet area for the rear (vertical/cruise) engines in hovering flight, the inlet cowls could be displaced forward to provide an additional air inlet slot.

Preliminary testing was protracted, and preparation exceedingly thorough, with the result that the actual flight testing was completed without any major problems. On 8 October, 1963, four years after the contract was placed, the aircraft completed its first full flight, *i.e.* vertical take-off, transition to forward flight, followed by vertical landing. The last flights of the VJ 101 X-2 took place early in 1969.

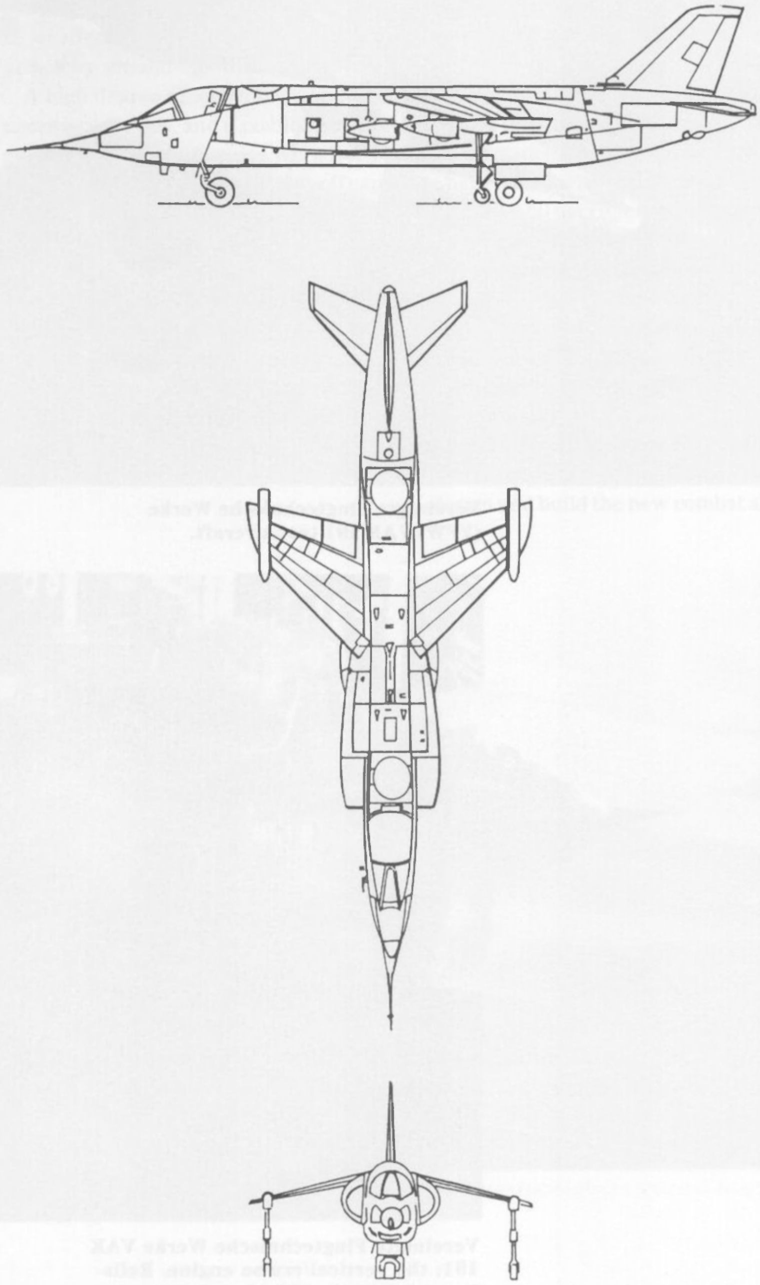
Specification of VAK 191B

Engines	One Rolls-Royce/MTU RB.193-12 Two Rolls-Royce RB.162-81
Thrust	1 × 4.5 kN (4,600 kg) 2 × 2.65 kN (2,700 kg)
Wingspan	6.20 m
Length	14.72 m
Wing area	12.5 sq m
All-up weight	7,500-9,000 kg

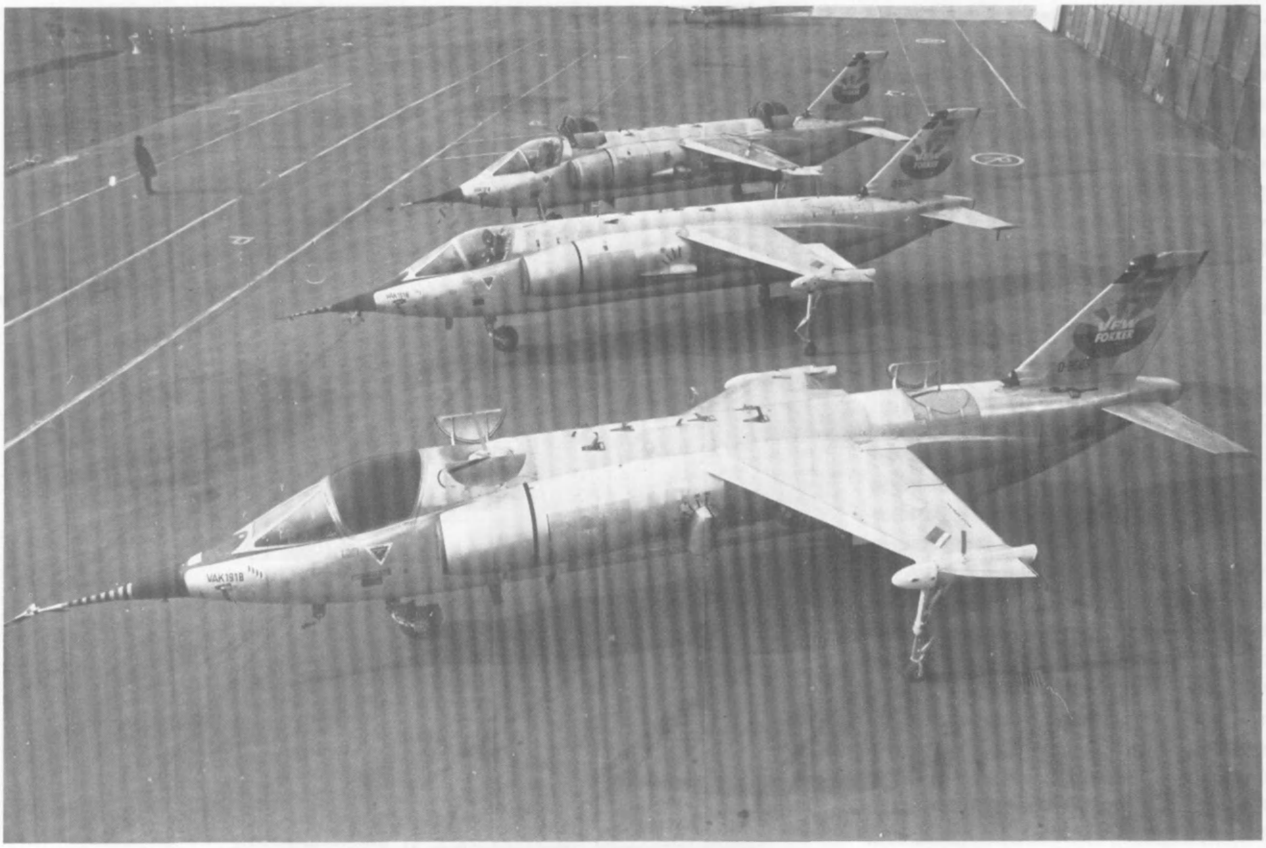
The VAK 191 of the Vereinigte Flugtechnische Werke

Work was begun on a second vertical take-off aircraft early in 1965 by two companies working in collaboration: VFW (Vereinigte Flugtechnische Werke Bremen) and Fiat (Turin). This machine was not intended for supersonic flight at great altitudes, but for troop support at very low altitudes. The Italian company subsequently withdrew from the project, and VFW continued it to its completion. As the VAK 191 was intended to support ground forces, it had to be able to take off and land vertically from unprepared sites in the immediate vicinity of the troops. The wing area was small and the wing loading correspondingly high, in an effort to obtain high speed and reduce sensitivity to gusts. In low-level flight at high speed, gusts place very high and very frequent loads on an aircraft, and restrict the combat capability of the crew to an extraordinary degree.

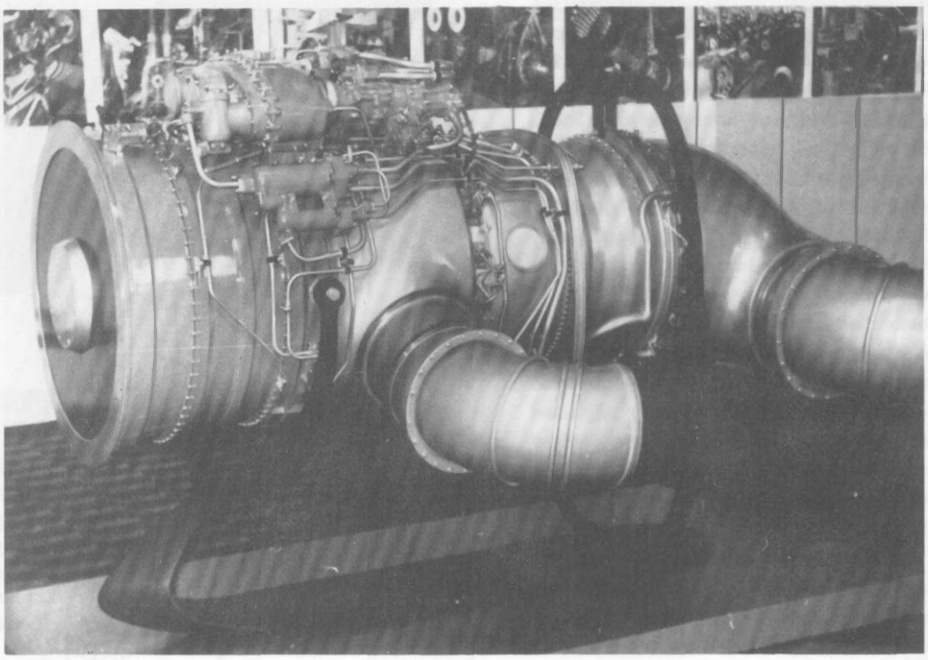
The engines had to supply about 20 per cent more thrust than the aircraft's take-off weight to allow vertical take-off, and to keep their weight as low as possible, two supplementary, ultra-light vertical thrust engines were incorporated in addition to the cruise engine, which were only used for take-off and landing. This arrangement made it possible to specify a cruise engine of a size which would operate within a favourable power setting in normal flight. The main engine, a by-pass or two-cycle unit, was located at the aircraft's centre of gravity. In normal flight the by-pass jet and the exhaust jet were directed to the rear from two nozzles on the fuselage sides, and thus supplied forward thrust. For vertical take-off and landing the nozzles were rotated. Their downward thrust produced about half the required vertical power, while the other half was supplied by two extremely light vertical thrust



Vereinigte Flugtechnische Werke VAK 191



Vereinigte Flugtechnische Werke (VFW) VAK 191 test aircraft.



Vereinigte Flugtechnische Werke VAK 191: the vertical/cruise engine. Rolls-Royce/MTU RB. 193-12; 4,600 kg thrust.

engines. The inlet and outlet of these engines were covered by flaps in normal flight. In hovering flight control around the three axes was achieved via controllable nozzles at the nose, the tail and the wingtips, through which air was blown. The air was tapped from the compressor and fed to the nozzles through ducts inside the aircraft. As on the VJ 101, an extra slot in the air inlet ensured an adequate air supply to the cruise engine in the hover.

The VAK 191 was planned to fulfil the role of close-range single-seat support fighter, but only the test aircraft were built. The airframe was an orthodox light-metal structure. The one-piece wing had several spars, very thin profiles and the leading-edge sweep angle was almost 45 degrees. The tail surfaces were also sharply swept back. The nosewheel undercarriage was arranged with the rear wheels close together on the centreline, to provide clearance for the jet efflux of the cruise engine. Support wheels were fitted at the wingtips.

The aircraft was completed in April 1970. After careful testing of the machine's hovering characteristics, it was flown for the first time on 10 September, 1971. On 26 October, 1972, the whole cycle of vertical take-off, normal forward flight and vertical landing, was undertaken for the first time. Soon after this the Federal Government stopped financing of the programme.

Further development of the two vertical take-off designs was defeated by a change in defence strategy, in addition to a shortage of funds and certain other circumstances. The essential fact was that it was becoming increasingly important to have an aircraft which could fly at high speed very close to the ground, in order to evade detection by radar and thus attack by ground-based weapons.

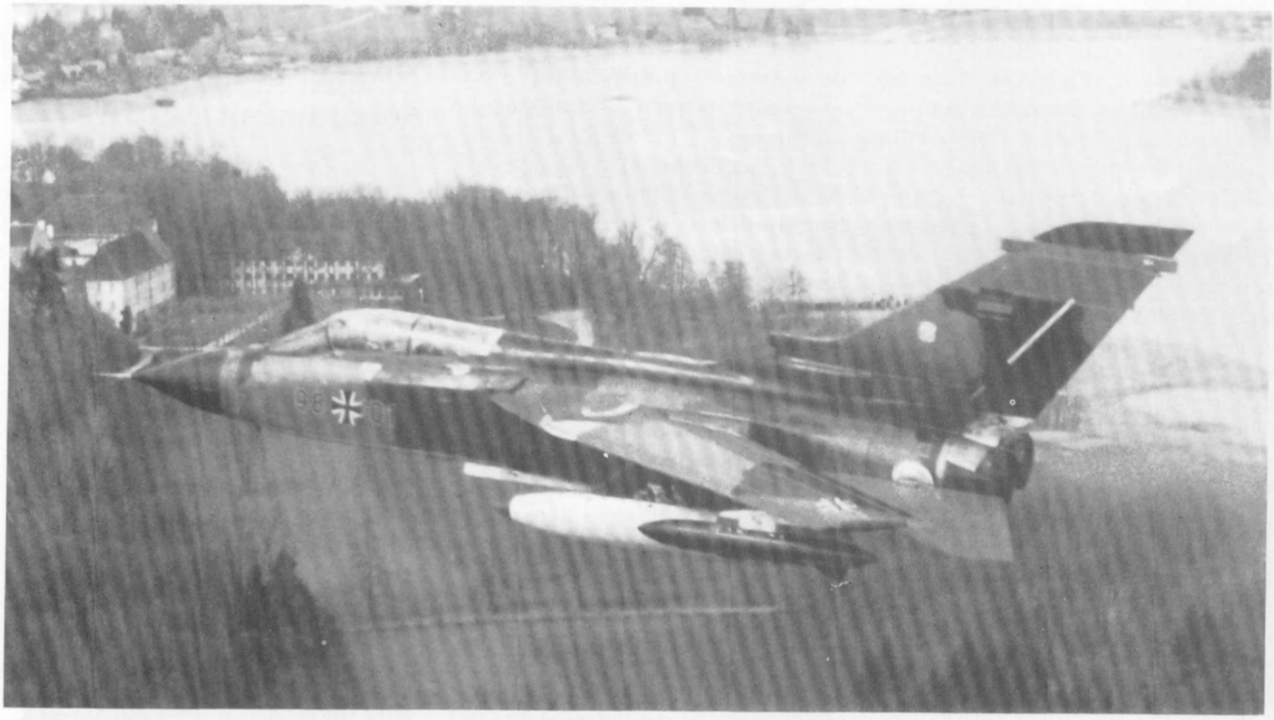
A high degree of sweepback appeared necessary for this, and if possible variable sweep, but the authorities were not yet ready to give up the vertical take-off capability. Work began in collaboration with American firms on a vertical take-off aircraft with variable-sweep wings (swing wing). Since it had been necessary to ensure that the machine had sufficient range for use in the United States, and since it combined so many technical innovations, it is hardly surprising that the outcome was too complex, too heavy and too expensive.

The NKF (Neues Kampfflugzeug — New Combat Aircraft) — Requirement (MRCA)

A new approach was tried. Vertical take-off was abandoned in favour of a 'short take-off' requirement, in the hope that the machine would be cheaper. As a co-operative development by the Western European nations, a fighter-bomber was planned under the designation NKF — Neues Kampfflugzeug, with a target weight of 10 tons. As the project got under way, it became evident that the expected performance was not attainable with such a light machine, and an increase in weight of at least 50 per cent would be necessary. As a result, several of the countries which had participated originally withdrew from the project, and the three partners remaining in the new development, now known as the MRCA (Multi Role Combat Aircraft), were the Federal Republic of Germany, Britain and Italy.

On 26 March, 1969, a new organisation — Panavia Aircraft GmbH — was set up to design and build the new combat aircraft.

Vereinigte Flugtechnische Werke VAK 191 in hovering flight.



Panavia Tornado. Wings swept for high-speed flight.

Panavia Tornado. Wings swung forward, flaps and slats extended in take-off and landing configuration.

Panavia Tornado: Specification

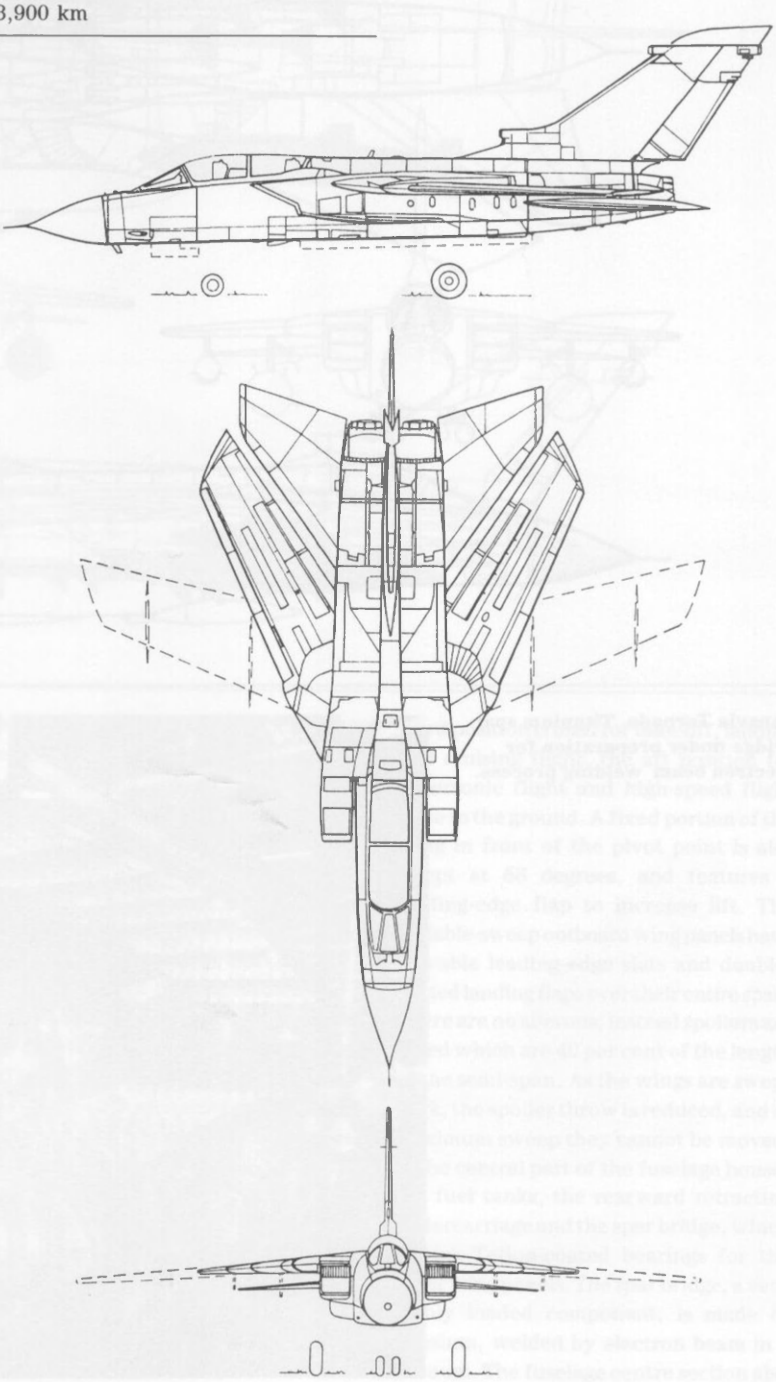
Engines	Two Turbo Union RB.109-34 R
Static thrust	40 kN, 4,100 kg without afterburner 71 kN, 7,000 kg with afterburner
Wingspan	13.6/8.6 m
Length	16.7 m 18.1 m for the Air Defence version
Wing area	26.6 sq m
Empty weight	14,091 kg
All-up weight	26,500 kg
Maximum speed	Mach 2.2
Radius of action on interdiction mission	1,400 km
Ferry range	3,900 km

This was a co-operative effort by the three firms Messerschmitt-Bolkow-Blohm, the British Aircraft Corporation (later British Aerospace) and Aeritalia, the companies awarded the contracts by their respective Governments to develop the MRCA. During the period in which the design gradually assumed its final form, further requirements were included, and the aircraft became considerably heavier compared with the initial plans. In its external form little changed, but the wing loading became higher.

The best solution to the task which had been set appeared to be a two-seat, twin-engined supersonic aircraft with variable sweep, partly in deference to the considerably larger American General Dynamics F-111, and its intended roles were as follows:

1. Close-range air support/battlefield interdiction
2. Interdiction/counter air strike
3. Air superiority
4. Interception/air defence
5. Naval strike
6. Reconnaissance.

The fundamental design was completed in August 1972. The first test aircraft flew on 14 August, 1974, and by February 1977 a total of nine machines were flying and participating in the various test programmes in the three partner countries. On 29 July, 1976, the three Governments concerned agreed to purchase a total of 809 aircraft, for which the name Tornado had been chosen. Of these 385 were destined for Britain, 324 for the Federal Republic of Germany, and 100 for Italy.



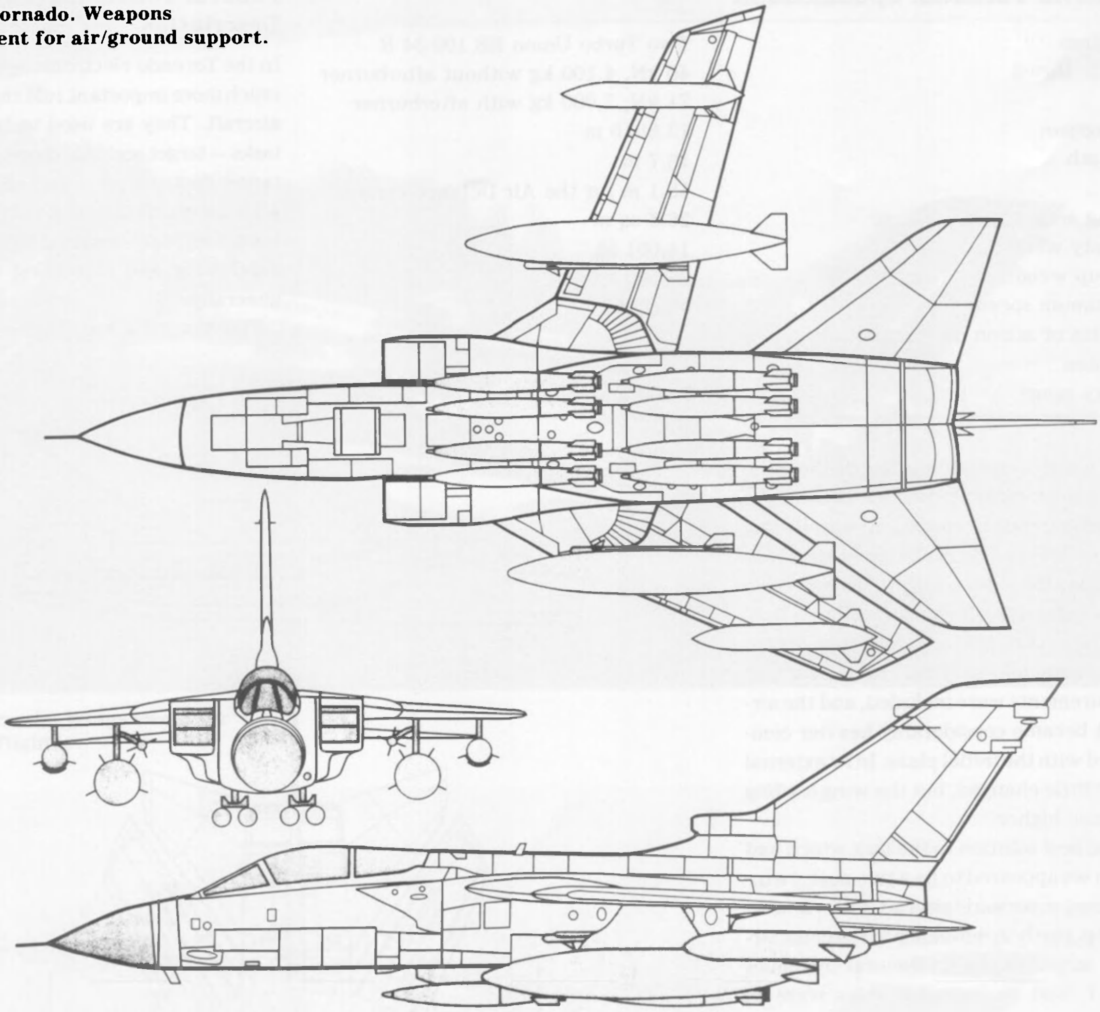
Panavia Tornado

Panavia Tornado: Technical Description

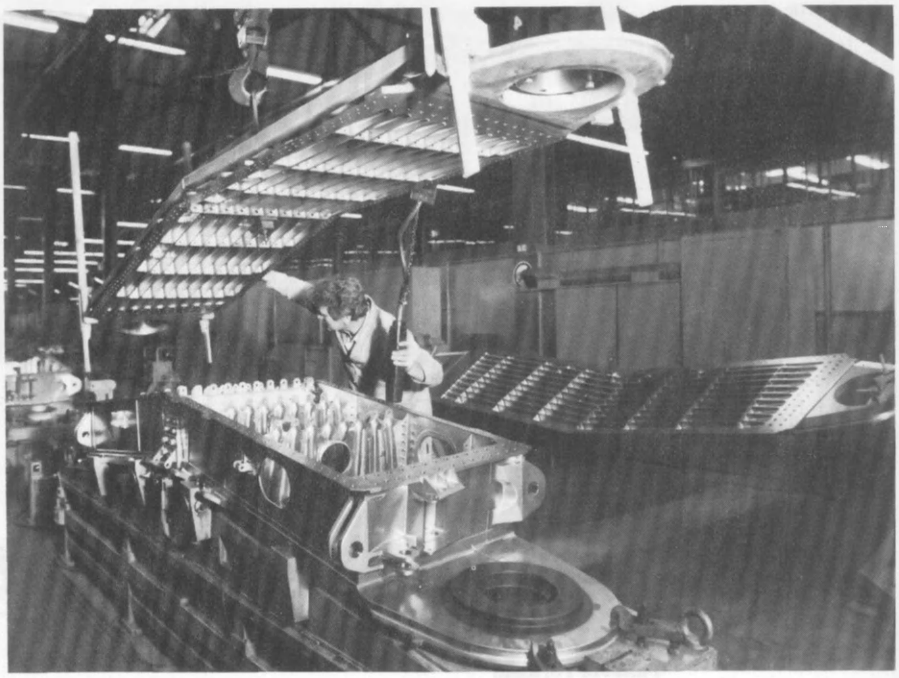
In the Tornado electronic systems have a much more important role than in earlier aircraft. They are used to fulfil combat tasks — target seeking, target location and target destruction — and also to aid the pilot, especially in low-level flight following the terrain — contour flying — and for controlling and stabilising the aircraft generally.

The aircraft's broad speed range and

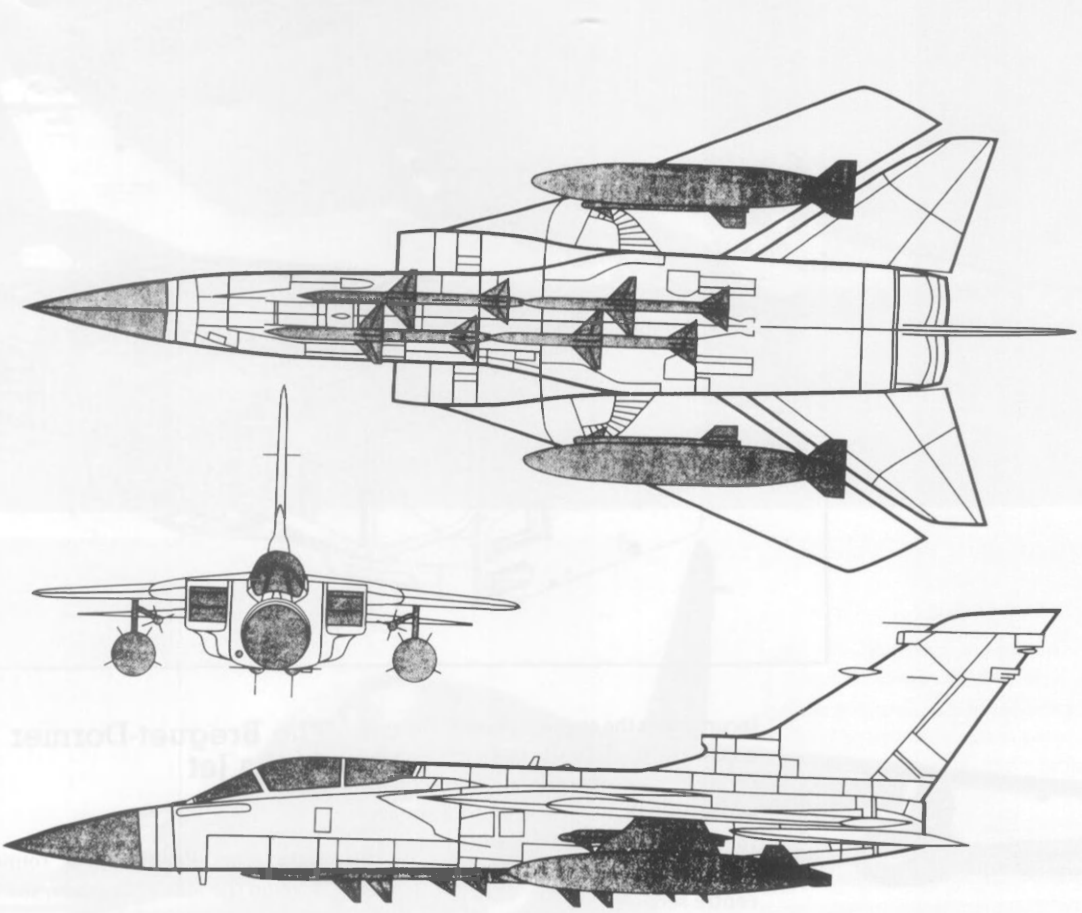
Panavia Tornado. Weapons arrangement for air/ground support.



Panavia Tornado. Titanium spar bridge under preparation for electron beam welding process.



Panavia Tornado. Weapons arrangement for aerial defence.



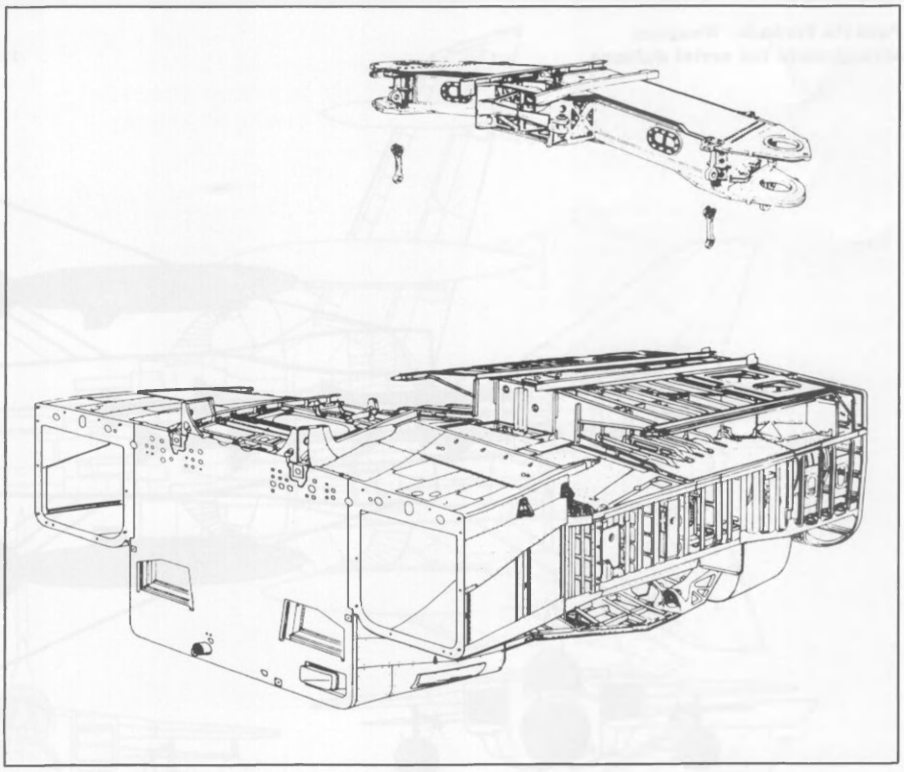
swing-wing capability incur such massive alterations in its aerodynamic characteristics that the pilot cannot cope alone. He needs an electronic system which makes the flying characteristics acceptable (stability and damping), and it must also undertake his piloting commands precisely. The first requirement is met by gyros and computers, the second by electrically regulated, hydraulic control systems. The pilot no longer feels the control pressures produced by the control surfaces, which he would normally rely on for information about his speed and flight situation. Between him and the control surfaces the only connections are electrical, and what he feels is a simulation produced by a computer.

In spite of the multiplicity of electronic aids, a second, rear crew member is necessary to undertake most combat tasks, and in fact his is often the main role. The only task which is entirely in the hands of the pilot is air-to-air combat, for which all the immediately essential data is reflected on the front screen (head-up display). A detailed description of all the avionics, including the front and rear radar warning equipment, etc is far beyond the scope of this book. The fact that electronic systems of all kinds account for 21 per cent of the overall cost of the aircraft may give some indication of its sophistication.

Manufacture and assembly of the Tornado is subdivided as follows: fuselage front and rear sections, including tail surfaces — BAe (British Aerospace), Britain; fuselage centre section — MBB, Federal Republic of Germany; wings — Aeritalia, Italy.

The wings are made largely of light alloy, with machines, load-bearing skins, and rotate around a pivot set slightly outboard of the fuselage. In its forward position the wing leading edge is swept by 23 degrees, in the rear position 68 degrees. The forward position is used for take-off, landing and cruising flight, the aft position for supersonic flight and high-speed flight close to the ground. A fixed portion of the wing in front of the pivot point is also swept at 68 degrees, and features a leading-edge flap to increase lift. The variable-sweep outboard wing panels have movable leading-edge slats and double-slotted landing flaps over their entire span. There are no ailerons; instead spoilers are fitted which are 40 per cent of the length of the semi-span. As the wings are swept back, the spoiler throw is reduced, and at maximum sweep they cannot be moved.

The central part of the fuselage houses the fuel tanks, the rearward retracting undercarriage and the spar bridge, which carries Teflon-coated bearings for the outer wing panels. The spar bridge, a very highly loaded component, is made of titanium, welded by electron beam in a vacuum. The fuselage centre section also



Panavia Tornado. Fuselage centre section and spar bridge with bearings for swing-wing mechanism.

incorporates the engine air inlets. They are adjusted automatically to match varying conditions of operation, especially for supersonic flight. The actuating systems for the air inlets and the wing sweeping mechanism are also located in the fuselage centre section.

The rear part of the fuselage houses the engines. It also carries the vertical stabiliser, which consists of a fixed fin and movable rudder, and the two horizontal stabiliser panels, which work as elevators when moved in the same direction, and as ailerons when moved in opposite directions. Large flaps can be extended from the top of the rear section of the fuselage to act as air-brakes.

The power plants, a combined development by Rolls-Royce (Britain), MTU (Federal Republic) and Fiat (Italy), are by-pass engines with afterburners. Nozzle flaps are fitted, by means of which the direction of thrust can be reversed to provide a braking effect on landing.

The armament of the Tornado consists of two Mauser 27mm cannon of very high firing rate, provided with 150 rounds each, and rockets with heat-seeking heads for air targets. A wide range of guided and unguided weapons can be carried on three fuselage racks and two wing racks on each side, for use against ground targets.

The Breguet-Dornier Alpha Jet

Soon after Panavia was founded to develop the MRCA/Tornado, the French Government, which had been one of the original partners in the NKF project, sought the co-operation of the Federal Republic of Germany in producing an aircraft for basic and advanced training of combat pilots. A further intention was to convert the aircraft into a light fighter-bomber for ground-support duty. The Federal German Government was enthusiastic about the idea of an additional, light and cheap fighter-bomber to complement the Tornado. Two Franco-German teams took part in the contract competition: Dornier and Breguet, then still an independent company, and MBB and Süd-Aviation, also still independent. (In 1971 Breguet Aviation merged with Avions Marcel Dassault to form Dassault-Breguet.) In late July 1969 the Dornier-Breguet design was approved for further development. A decisive factor against the MBB-Süd-Aviation design was the high-set tailplane (about which there had been much argument within the team). The Luftwaffe's experience with the Lockhead F-104 Starfighter, with its high-set tailplane, had been dismal, and a series of crashes in civil

Dassault-Breguet/Dornier Alpha Jet front view.

Dassault-Breguet/Dornier Alpha Jet rear view.

aviation had been traced back to the same feature, which had led to the high-set tailplane being *the* subject for aerodynamicists.

A second important point in favour of the Dornier-Breguet design was that as a shoulder-wing machine it was better able to carry external loads than its competitor, with its low-wing layout.

At an early stage it was realised that the 1,000 kg thrust of the single Turbomeca-SNECMA Larzac engine would not be sufficient, and development began on the higher power Larzac 04, with a turbine inlet temperature of 1,130 degrees C and an air-cooled turbine.

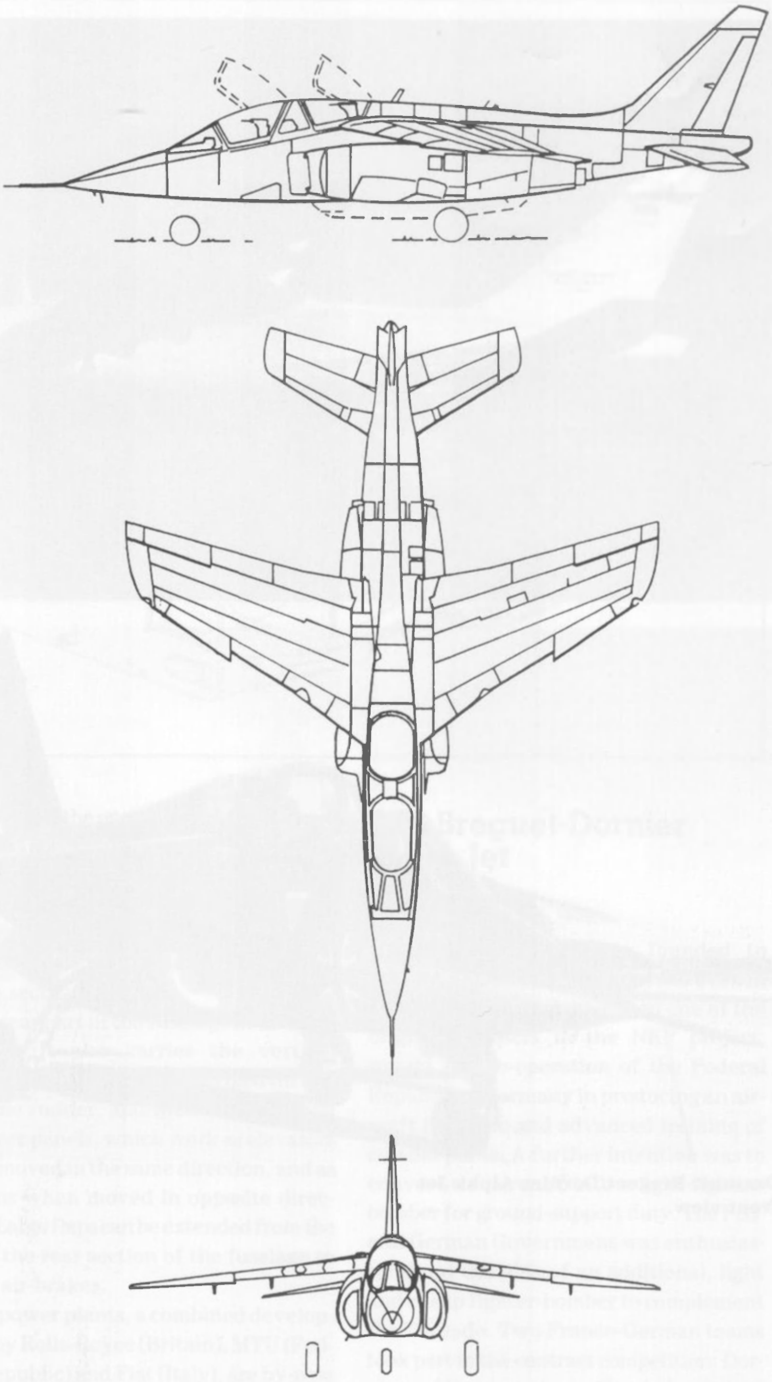
Technical Description

The Alpha Jet was planned for the following tasks:

Pilot training
Weapons training
Close-range air support
Battlefield interdiction

It is a twin-engined, two-seat shoulder-wing machine with 28 degree sweepback at the quarter-chord line. To guard against wing dropping in the stalled condition the wing leading edge is brought forward from the 60 per cent semi-span point, forming a 'sawtooth'. The wing is built in two panels, which are bolted to a centre section which is integral with the fuselage. The load-bearing wing skin is machined from light alloy, and much of the wing is used to hold fuel. Landing flaps, which when extended increase the wing chord, extend over two thirds of the wingspan. The fuselage consists basically of three main parts: front, centre and tail sections. The front section houses the two ejector seats, the rear one much higher than the other, and the nosewheel. In the centre section are the fuel tanks and the wide-track — 2.7m — undercarriage, which is retracted against the air flow into the engine cowlings, as is the nosewheel. The engines are fitted beneath large, folding fairings on either side of the fuselage at the rear. Neither the inlets nor the engines themselves are within the main fuselage structure; a design feature which greatly simplifies engine maintenance and replacement.

The armament consists of one 27mm Mauser cannon with 150 rounds, housed in a cowling under the fuselage. In addition a whole arsenal of rockets, guided and unguided weapons and extra guns can be mounted on two fixed racks on each wing.



Alpha Jet

Specification of Alpha Jet

Engines	Two Turbomeca-SNECMA Larzac04
Thrust	2 × 13.2 kN (2 × 1,350 kg)
Wingspan	9.11 m
Length	12.29 m
Wing area	17.50 sq m
Airframe weight	3,515 kg
All-up weight	5,000-7,250 kg
Maximum speed	Mach 0.85

The Future

The great majority of the Federal German Luftwaffe's fighter force will consist of Tornado and Alpha Jet aircraft in the decade which began in 1982. Their development has been dictated to a very great extent by the combat tasks allotted to them: destroying enemy air forces on the ground, the attack role in battles on the ground and at sea, and air support of ground-based troops. The classical task of the fighter/destroyer — combat against air targets - has retreated into the background. But the aircraft industry and the military are now debating whether a specialised fighter aircraft might not become a significant factor in air defence if new technologies are exploited. The principal hindrance to effective air-to-air defence is the restricted firing arc. For a fighter with machine-guns, cannon or unguided rockets the target can only be attacked from a relatively narrow sector, approaching from the rear. For the fighter equipped with heat-seeking guided missiles the sector is larger and funnel-shaped, but it is still not large enough.

The latest technology will raise the ratio of engine thrust to aircraft mass above unity, which will enable the aircraft to stand on its tail, so so speak, and change direction very quickly and in a very small space. The new problem is how best to exploit this enhanced manoeuvring capability to widen the firing field of the guided rockets. In fact, this represents a reversal of the conditions which once had led to movable armaments.

At the time the idea of widening the firing angle was not successful, but its failure is not necessarily proof that the idea was fundamentally unsound. A renewed effort will be required in order to open up new possibilities for air-to-air defence.

Notes

1. The first State/Military contract to the Wright brothers was awarded by the US Signal Corps.
2. Evidence of the validity of this view is to be found in Alexander Solzhenitsyn's book *August 1914*, where the Russian defeat in the battle of Tannenberg is largely blamed on their lack of aerial reconnaissance, in contrast to the efficiency of the German system.
3. Known at the time as parasol monoplanes, but classed as high-winger monoplanes. The Pfalz aircraft works at Speyer bought a licence for this aircraft which was part of the initial equipment for the Bavarian Army.
4. The same expert opinion is repeated in a similar memorandum by Lt Löwenhardt: 'As we now have an inferior fighter, the Staffel leader at the Front must seek out a suitable moment to attack. If no favourable opportunity presents itself while he still has petrol, he should return to base and try the attack another time.'
5. Richthofen's own Staffel.
6. See Student's notes on flight characteristics.
7. Brother of the later General Hans Speidel.
8. Hillman, W.: Shipbuilding.
9. From this point Heinkel aircraft were designated He, instead of HD for biplanes and HE monoplanes.
10. In January/February 1933 the He 70 set up six international speed records.
11. The standard initial training aircraft from 1939, the Bücker Bestmann, was a cantilever low-wing monoplane with two seats side by side.
12. The first Supermarine Type 224, a low-wing monoplane with inverted gull wing and fixed undercarriage faired into trousers, was built for the Rolls-Royce Goshawk engine with evaporative cooling. The wing leading edge was to act as condenser. The system did not work, and after a short period the engine, aircraft and evaporative cooling idea were abandoned.
13. The same process was repeated two years later. The He 119, built by Heinkel for the fast-bomber competition, equipped with the Daimler-Benz DB606 coupled engine, was planned for evaporative cooling. The steam separator system and the condenser pumps, etc, did not work, or not at first, but there were hopes of making it work. In the meantime a reasonably efficient block radiator installation was to be fitted in place of the evaporative cooling system and surface cooling. But the task was more difficult than with the He 112, as it would have been necessary to undertake a major redesign, which was not possible or feasible in the time available. Thus the radiator problem also helped the He 119 fast bomber into an early grave.
14. A 20mm weapon, developed by Rheinmetall-Borsig, which was abandoned in favour of the MG FF and MG 151.
15. Udet had become Chief Inspector of the fighter and dive-bomber pilots in January 1936. He became head of the LC Technical Office on 1 July, 1936.
16. The Junkers Ju 88 was the winner of a fast-bomber competition in 1935 over the Henschel Hs 127 and Messerschmitt Bf 162, a modified version of the Bf 110 to suit the fast-bomber specification. An interesting fact is that the Ju 88 also figured in the heavy fighter list for a time.
17. See the author's personal note in the introduction.
18. Speech by the LG on 13 February 1937 to the Commanders.
19. Hitler had demanded and enforced the annexation of the German-speaking Sudentenland into the Reich in September 1938.
20. On 11 July, 1938, the Bayerische Flugzeugwerke (Bavarian Aircraft Works) was renamed Messerschmitt AG, and after this date new types were designated Me instead of Bf. Existing types, such as the 109 and 110, retained the earlier designation in all official documents.
21. A rocket-propelled 21 cm grenade.
22. On the special aircraft, a destroyer/reconnaissance machine converted for bomb dropping, the ETC 500 (bomb racks) were fitted externally while the only external sign of the bomber version's attachments for the two 500 kg bombs was four 2 cm wide projections about 3 cm into the airflow.
23. GM-1: see the section dealing with 'High-altitude aircraft'.
24. The Fw 190 V4 was cancelled.
25. Major General Gollob, with 150 'kills' to his credit, was awarded the Ritterkreuz (Knight's Cross) with Eichenlaub (oak leaves) and Schwerter (swords) and Brillanten (diamonds), and was Captain in Command of the Luftwaffe test stations at this time.
26. Focke-Wulf aircraft after 1943 were designated Ta (from Kurt Tank's name) instead of Fw.
27. The same man who had flown the world record of 747 km/h in the He 100 on 30 March, 1939.
28. Today known as Dutch roll, an American term, after the flight manoeuvre known as the Falling leaf performed by Fokker in 1911.
29. Because of the undercarriage position, the bombs could only be accommodated far in front of the aircraft's centre of gravity. If guns and armour had been retained, the machine would have been unacceptably nose-heavy.
30. Me 264, long-range reconnaissance machine for use against sea targets. Four BMW 801D engines, weight 56 tons.
31. Rocket fighter for 'object guarding'. See Page 189.
32. Bü 181, initial training aircraft.
33. Ju 287, jet bomber with swept-forward wings. Six Junkers-Jumo 004 engines.
34. Me 262 jet fighter-bomber. See Page 170.
35. Ar 96 fighter trainer built in wood, to supersede the metal Ar 96. See Page 109.
36. Ju 388 night-fighter/destroyer. See Page 156.
37. Do 335 destroyer/night-fighter. See Page 163.
38. Ar 234 jet-powered reconnaissance air-

craft and bomber. See Page 173.

39. Ar 432 rough-field transport. Four Bramo 323 engines, 1,000 hp, weight 20 tons, replacement for the metal Ar 232B. See Page 138.

40. The project is of interest in that wind-tunnel tests had shown that the engines — the bodies causing the disturbances — should be distributed over the length of the fuselage.

41. See footnotes 35 and 39.

Appendix

Abbreviations

A II	Code for Section II of High Command
AOK	Armee Oberkommando — Army High Command
B aircraft	Training types (First World War)
BLV	Bau und Liefer Vorschriften — Construction and Delivery Requirements
C aircraft	Reconnaissance types (First World War)
DFS	Deutsche Forschungsanstalt für Segelflug — German Gliding Research Institute
DVL	Deutsche Versuchsanstalt für Luftfahrt — German Experimental Aviation Institute
E-Stelle	Erprobungsstelle — test centre
EWR	Entwicklungsring Süd — Süd Development Combine
Flz A	Code for the organisation for comparative testing of fighters at Berlin-Adlershaf
GL/C-E	General Luftzeugmeister/Technische Entwicklung — General Aeronautical Equipment Technical Development
GM 1	Laughing gas, nitrous oxide
Idflieg	Inspektion der Fliegertruppen — Air Inspectorate
IMKK	Inter-allied Military Control Commission
In WG	Weapons and Equipment Inspectorate
In 1	Inspektion 1 — A senior inspecting department of the German Army
K.M.	Kriegsministerium — War Ministry
Kogenluft	Kommandierender General der Luftstreitkräfte — Commanding General, Aerial Armed Forces
LC	Reichs Air Ministry Technical Office
LC II	Technical Office Aircraft Development Division
MW (50)	Water-methanol mixture (50:50)
Ob d L	Oberkommando des Luftwaffe — Air Force High Command
RLM	Reichsluftfahrtministerium — Reichs Air Ministry
RRG	Rhön-Rossitten Gesellschaft (für Segelflug) — Rhön-Rossitten Company (for sailplaning)
RVM	Reichsverkehrsministerium — Reichs Transport Ministry
S-testing	Schnell-Erprobung — Accelerated testing
TA (L)	Troops Office, air; Air Defence Office
TL	Turbinen Luftstrahltriebwerk — Turbo (jet) engine
ZMo	Zentrale Moskau — Moscow Centre

Units of Measurement

Aircraft	
Length, wingspan, height:	**m**
Area:	**sq m**
Weight:	**kg**
Speed:	**km/h**
Rate of climb:	**m/sec**
Piston Engines	
Power:	**hp (kW in tables only)**
Specific fuel consumption:	**kg/hp/hr**
Jet Engines	
Thrust:	**kg**
Specific fuel consumption:	**kg/hp/hr**
Rocket Engines	
Thrust:	**kg**

Technical Terms

Bracing: wires or cables between spars and interplane struts to transfer the tension forces in the wing structure.

Cabane: the centre section of the wing of a high-wing or multi-wing aircraft set on struts above the fuselage.

Control surface balance: a means of reducing the control forces. Moments caused by control surface deflection (aileron, elevator, rudder) can be reduced by locating part of that surface in front of the pivot axis. Balance surfaces as used on the Fokker Triplane and Pfalz D III are all forms of aerodynamic or horn balances.

Diagonal bracing: the use of wires under tension to stiffen a rectangular framework, and prevent it deforming in one plane.

Flutter: a combined vibration or oscillation in the torsional and bending planes of a wing, occurring at high speed — the flutter speed. Can result in the destruction of the wing. Aircraft are only operationally safe below the flutter speed.

Flying characteristics: behaviour of the aircraft under the influence of the pilot's control commands and outside effects (gusts), its stability, *i.e.* its ability to return to the original altitude after being disturbed. Also includes the hand and foot forces required to operate the controls.

Former: fuselage component set at right-angles to the fuselage centreline, giving the fuselage its cross-sectional form, and stiffening the skin.

Ground-loop: spiral track of an aircraft on the ground which occurs as a result of asymmetrical forces, due to instability around the vertical axis and a lack of rudder effectiveness.

Interplane strut: strut located between the wings of biplanes: single-bay — one pair of struts (or one I-strut) on each side of the fuselage; two-bay — two pairs of struts on each side.

Manoeuvrability: 1. A measure of an aircraft's ability to make a rotation around the longitudinal axis in the shortest possible time (using aileron deflection). 2. A measure of an aircraft's ability to make a turn in the shortest possible time.

Principal axes: the axes running through the aircraft's centre of gravity in a right-angled co-ordinate system. Roll movement occurs around the longitudinal axis, and is controlled by the ailerons. Pitch movement occurs around the transverse axis, and is controlled by the elevator. Yaw movement occurs around the vertical axis, and is controlled by the rudder.

Projecting radiator: movable radiator which projects out of the side of the fuselage into the airstream.

Rib: wing (or tail) component running parallel to the direction of flight and perpendicular to the spars, endowing the surfaces with the required aerofoil section, and transferring the air forces to the spars.

Roll: banking movement; rotation of the aircraft around the longitudinal axis.

Spar: component running in a spanwise direction through the wing (or tail), designed to absorb the forces acting on the wing (the main structural member/s).

Spin: flight condition in which the aircraft, after stalling, falls into a rotary movement after the airflow over one wing separates (or as a result of extreme control-surface movements), which continues in a steep downward path. If the vertical stabiliser is inadequate, it can be difficult or impossible to recover from the spin.

Spoiler: narrow blade located at the wingtip at the aileron position, which can be projected out of the upper surface to supplement the action of the aileron, or replace it altogether.

Stability: the aircraft's ability to return to a stable flight situation after being disturbed by an involuntary or voluntary action.

Stall: by pulling back the control column the aircraft's angle of attack is increased. At the point of maximum lift the airflow over the wings begins to separate, and lift begins to fall. Pulling back past this point leads to a stalled condition.

Stringer: wood strips or metal profiles running at right-angles to the ribs or formers, designed to transfer the longitudinal forces or stiffen the skin.

Supercharged (literally over-compressed): term used of engines which were throttled back up to a particular altitude, in order to avoid overloading them.

Surface cooling: method of removing the heat in the cooling water by evaporation, which occurs when pressure is reduced, and condensation of the resultant steam on the inside of the aircraft's wing skin. The condensate is pumped back into the cooling system to recirculate.

Tip-stall: spontaneous roll movement (rotation around the fuselage centreline), caused by separation of the airflow over one wing at the stall (see Stall).

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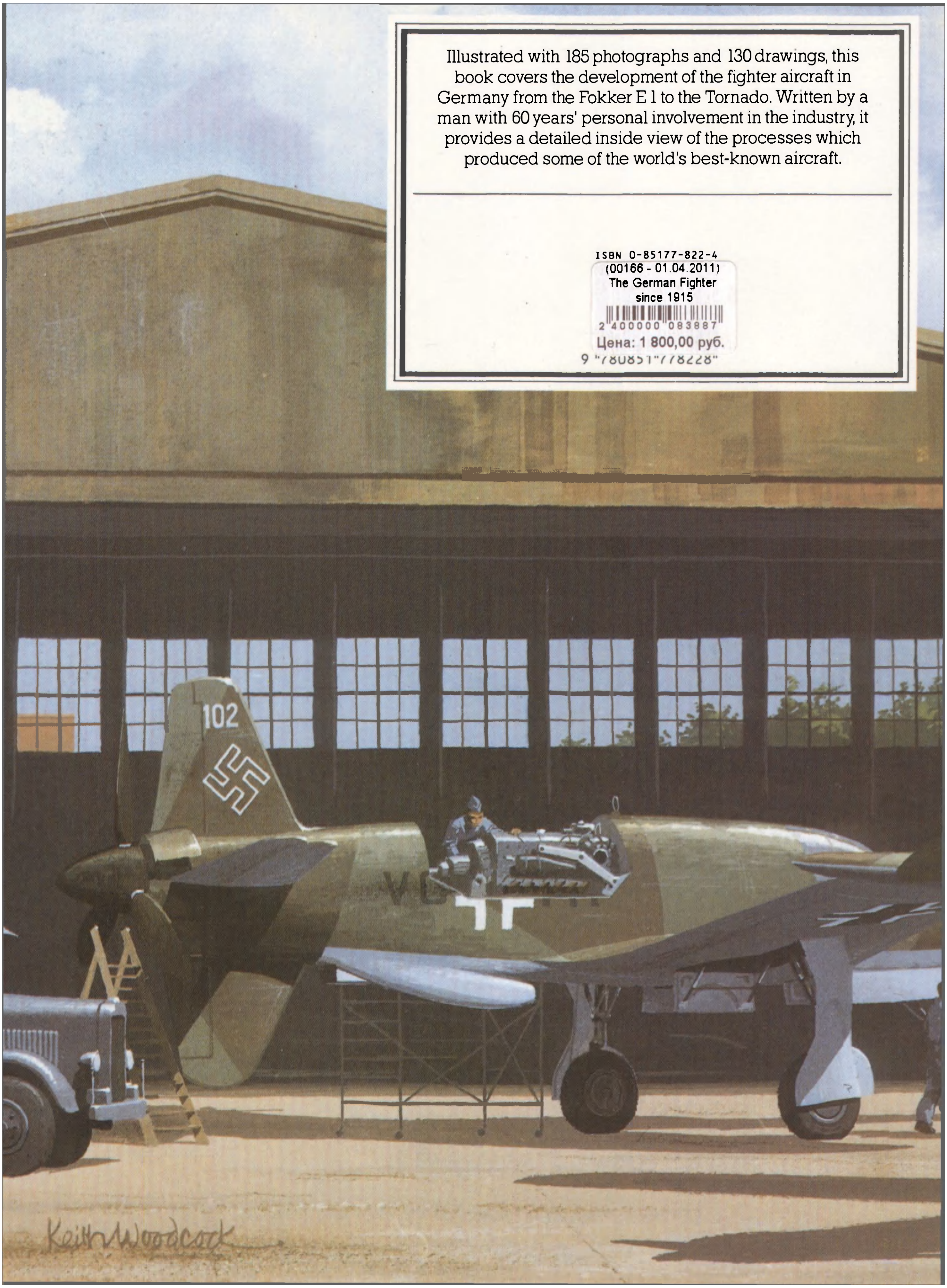
The Author

Rüdiger Kosin, born at Neustadt in West Prussia in 1909, built his first model aircraft at the age of twelve, together with his younger brother, and collaborated with him again to build a glider when he was seventeen. July 1927 and September 1928 gliding school at Rossitten. From autumn 1928 to summer 1933 studied at the Technische Hochschule (Technical University) at Darmstadt; member of the Akademische Fliegergruppe — University Flying Group. During this period trained as powered-aircraft pilot, and, as final degree project, on design and construction of the 'Windspiel' glider (distance record, 1934). After gaining his Diploma, further training as aircraft construction foreman in industry, flying training, and experience at the Rechlin test centre. After passing exams as 'Flugbaumeister' — aircraft building master craftsman — was design office group director and engineer pilot in the experimental flight section of the Ernst Heinkel aircraft company at Rostock-Marienehe. At the turn of the year 1936/37 same activity at the Arado aircraft works in Brandenburg on the Havel. From 1941 to the end of the war was director of the aerodynamic design division. From October 1945 to May 1946 wrote a report for the Royal Air Force. From May to October 1946 resided in the British Interrogation Centre in Wimbledon. November 1946 to July 1950 worked in France — Decize (Nievre) — in the Oestrich group on jet engine development. July 1950 accepted an offer from Fokker in Amsterdam. Design of a supersonic fighter. When the firm withdrew from the project, accepted an offer from the U.S. Air Force to work in America on the continuation of a development process in Germany interrupted by the war. From January 1952 to July 1955 worked in Wright Air Development Center in Dayton, Ohio. In July 1955 accepted an offer from the Northrop Corporation, Los Angeles, California. Worked as Research Scientist, director of the design office, project director and finally, until December 1968, as Technical Assistant, Vice President Engineering. After 17 years in the USA and 23 years abroad in all, returned to Germany. From January 1969 to retirement in December 1975 director of preliminary development in the aircraft division of the firm of Messerschmitt-Bolkow-Blohm GmbH in Ottobrunn near Munich.



Illustrated with 185 photographs and 130 drawings, this book covers the development of the fighter aircraft in Germany from the Fokker E 1 to the Tornado. Written by a man with 60 years' personal involvement in the industry, it provides a detailed inside view of the processes which produced some of the world's best-known aircraft.

ISBN 0-85177-822-4